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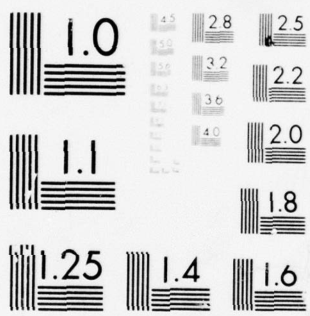

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REPORT

VOLUME II (Appendix I)

Methodology to Quantify the Potential Net Economic Consequences of Increased NATO Commonality, Standardization and Specialization

Prepared for:

The International Economic Affairs Directorate
Office of the Assistant Secretary of Defense
International Security Affairs

In response to:

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By:

C & L ASSOCIATES, INC.
10871 Spring Knoll Drive
Potomac, Maryland 20854

as

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2401 Research Boulevard, Rockville Maryland 20850

METHODOLOGY TO QUANTIFY THE POTENTIAL NET

ECONOMIC CONSEQUENCES OF INCREASED NATO

COMMONALITY, STANDARDIZATION AND SPECIALIZATION

Prepared for:

The International Economic Affairs Directorate
Office of the Assistant Secretary of Defense
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This study defines and demonstrates interrelated methodologies for estimating the costs of cooperative NATO weapons systems production programs for (a) individual programs (the MICRO methodology) and (b) NATO Alliance member nations (the MACRO methodology). The MICRO methodology is based on standard cost estimating techniques and requires detailed input data concerning production factors. The MACRO methodology relies on production data from analogous industrial (OVER)

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(20) Abstract

activities in combination with gross expected major system acquisitions to estimate gross economies available to the Alliance from utilization of least cost production option. Cost estimates derived by both MICRO and MACRO methodologies are for demonstration purposes only.

Cost - Quantity Relationships: A Survey of U.K., European and U.S. Evidence

by

Keith Hartley

Reader and NATO Research Fellow,
University of York,
U.K.

Contents

	Introduction
Chapter 1	Theory and Method
Chapter 2	Industrial Cost-Quantity Studies
Chapter 3	Industry Case Studies and International Competition
Chapter 4	Conclusions

Introduction

Standardization is believed to offer major cost savings, but there are few published studies which provide any evidence. Guesses abound. 'One can only guess how much on the average European NATO Allies pay for major equipment as compared with US prices - 10-20% might be a reasonable guess.'[1] This study concentrates on the possible savings from standardization in weapons production. The military benefits and the savings in operating costs are not considered. Such savings could be substantial. For example, the ownership and operating costs of a modern combat aircraft are at least equal to its acquisition costs; potential economies of up to 50% in Belgium and Dutch support units have been suggested through co-operation.[2]

Currently, standardization resembles a hazardous voyage of exploration into the unknown! It is not intended to comment upon its desirability.[3] Instead, this paper reviews the available evidence from industrial economics and international trade studies to see whether it provides any insights into the magnitude of the possible gains from weapons standardization in production. Chapter 1 defines the basic concepts of scale and learning economies. It presents an analytical framework which can be applied to standardization policies and carefully specifies the assumptions and limitations of the model. Chapter 2

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1. A. Marshall, NATO Defence Planning in S. Enke (ed.), Defence Management, Prentice-Hall, 1967, p.364.

2. J. Nelson, et al, A Weapon System Life Cycle Overview, Rand, R-1452, 1974; G. Ashcroft, Military Logistic Systems in NATO, Part II 11SS, Adelphi Paper 68, London, June 1970, p.20.

3. K. Hartley and A. Peacock, Combined Defence and International Economic Co-operation, The World Economy, June 1978; K. Hartley, NATO: Standardization and Nationalism: An Economists View, RUSI Journal, forthcoming. E. Vandevanter, Co-Ordinated Weapons Production in NATO, Rand, RM4169, 1964. D. Mack-Forlist and A. Newman, The Conversion of Shipbuilding from Military to Civilian Markets, Praeger, 1970.

presents and evaluates the available evidence on cost-quantity relationships, especially in the UK and Western Europe. International trade studies are used to indicate the possible gains from free trade in weapons and comparisons are made between Europe and the USA. It is shown that between the USA and Europe, differences in the length of production run may affect costs more than differences in plant sizes - and this source of cost reduction is probably more important in assembly-line or job-order type plants than in continuous process plants (e.g. oil refineries). Chapter 3 considers three industries in detail, namely motor vehicles, steel and aerospace. Each was chosen to illustrate specific aspects of our methodology - namely scale, learning and free trade effects. The analysis of aerospace also presents evidence on alternative standardization policies, including joint projects and co-production. A final chapter (4) presents our conclusions - scale economies, broadly defined, could give savings of 10% and free trade (plus competition) might result in further gains of 10%.

Chapter I Theory and Method

A. Theory: Definitions, Assumptions and Estimation

1.1 The Size of Firms and Economies of Scale: The Predictions of Economic Theory

Economic theory explains the size of a firm in terms of its aims (e.g. profit - or sales-maximisation) and the underlying demand and cost conditions. The traditional U-shaped long-run average cost curve (LAC), reflecting economies and dis-economies of scale, represents the cost factors determining firm size. Such a cost curve or scale curve assumes given factor prices and technical knowledge, as well as cost-minimising behaviour by firms. It refers to the output of a single product or service per period, usually per annum.

Economies of scale show the reductions in unit production costs when a firm is able to increase its size by varying all factor inputs: they correspond to the declining portion of the LAC curve. Such economies are available at the plant and firm level. They arise from technical factors associated with larger scale plants (e.g. division of labour; indivisibility of plant and machinery), or from economies in management, R & D, marketing and finance associated with operating a larger firm which may be a single or multi-plant enterprise.[1]

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1. A Silberston, Economies of Scale in Theory and Practice, Economic Journal, (Supplement), March 1972; Keith Hartley, Problems of Economic Policy, Allen and Unwin, London 1977, Chps. 9 and 10.

Once scale economies are exhausted, unit costs cease to fall and this point, corresponding to the minimum on a LAC curve, defines the optimum size of firm. Standard theory predicts that further increases in firm size beyond the optimum will encounter dis-economies of scale and rising unit costs, as the managerial task of co-ordination is reputed to become increasingly more complex and costlier (i.e. control loss).[1]

The relationship between size of firm and unit costs is one of the determinants of an industry's structure. Where scale economies are substantial, a domestic market might only be able to support one or a relatively small number of firms, so that there will be a conflict between efficient scale and competition. The price of efficient scale might be monopoly, with possible adverse effects on prices (including spares), outputs, technical efficiency, choice and innovation. In fact, evidence on concentration provides an indication of the extent and source of scale economies in an industry. Where there are substantial plant production economies and few economies at the firm level, then enterprises will operate a few large plants. Alternatively, the existence of a large number of plants per firm suggests that there are few plant production economies and mainly firm level economies.

1.2 The General Evidence on Scale Curves

Much of the empirical work on scale curves has been restricted to technical or plant level economies. Some of the industries are by

1. O.E. Williamson, Hierarchical control and optimum firm size, Journal of Political Economy, April 1967.

no stretch of the imagination "key" sectors (e.g. books, dyes and warp knitting). Nor are there many studies of costs in defence industries, so that it is necessary to use evidence from "related" sectors as possible proxies for scale curves in weapons. In general, the evidence on LAC curves in the UK, Western Europe and the USA shows that typically they are L-shaped, sloping downwards at first and then tending to become horizontal. The point at which the curve becomes horizontal defines the minimum optimum or efficient scale (mes). There appears to be little support for dis-economies of scale: this may reflect their complete absence or the fact that in general firms have chosen to avoid such sizes. However, whilst the evidence appears to conflict with the standard U-shaped LAC curve, its acceptance depends on the validity of the empirical work.

Estimating scale-curves requires that variations in factor prices, efficiency and technical knowledge be isolated and held constant. Difficult though this might be within a country, the estimation problems are much greater between nations. A scale curve for, say, tank manufacture in France with a given set of factor prices may differ from that for another economy with different relative factor prices. In other words, estimates of economies of scale in France or the UK cannot be assumed to apply to other countries. Having recognised the point, one UK study found industries where there were technical limits on the scope for factor substitution (labour for capital) and cases where the costs of operating capital equipment were

a small proportion of costs. Thus, it was suggested that '... our conclusions would probably apply to many other countries even if relative factor prices were appreciably different.'[1] Our survey partly supports this conclusion since there are a number of international studies of industries which treat the UK and Western Europe as a reasonably homogeneous unit with similar scale curves; these differ from US experience.[2]

1.3 Estimating Scale Curves

Various techniques are used to estimate scale curves. Since these estimating methods form the basis of the industry studies reported in this survey, some general understanding of their limitations is required before applying uncritically the estimated scale factors to indicate the possible "savings" from weapons standardisation. Three estimating techniques are available, namely, statistical cost analysis, engineering estimates and the survivor technique:

a) Statistical cost analysis uses available and actual cost data from firms producing different levels of output. With this method, problems arise because of differences between economists' and accountants concepts of cost (i.e. opportunity costs v money outlays), and the difficulties of valuing fixed capital assets based on old, antiquated technology (e.g. different firms use different depreciation methods). Confusions are likely between short-run and LAC curves and, unless all firms are efficient, statistical "best fits" might not be least cost.

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1. C. Pratten and R.M. Dean, The Economies of Large-Scale Production in British Industry, Department of Applied Economics, Cambridge, Occasional Paper 3, 1965 p.13.

2. D. Burn and B. Epstein, Realities of Free Trade: Two Industry Studie Allen and Unwin, London, 1972.

Moreover, there are the standard difficulties of holding constant all causes of cost variations other than scale (e.g. factor prices, technology) and of allocating costs for a single product in a multi-product firm.[1] In the circumstances, it has been asserted that cross-section contemporaneous accounting data for different firms give little, if any, information on scale economies: '... accounting cost data tell us nothing about _ex ante_ costs of outputs of different sizes, but only about the efficiency of the capital market in revaluing assets.'[2] Further confusions are likely once it is recognised that the existing distribution of firms in any industry reflects both "mistakes" and planned differences designed to exploit any comparative ability.

b) _Engineering estimates_ use experts (managers and engineers) to estimate the cost of production for hypothetical plants of different scale.[3] This approach is reputed to allow other influences to be held constant, especially technical knowledge and relative factor prices. However, the method usually concentrates on plant economies in production, neglecting firm level economies. It is also subject to the limitations of interview - questionnaire techniques, with a possible bias towards finding large scale economies. For example, the best managers are likely to be interviewed and they might be optimistic about their abilities to exploit scale economies at output

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1. C. Smith, A Survey of Empirical Evidence on Economies of Scale, _Business Concentration and Price Policy_, Princeton, NBER, 1955.

2. M. Friedman, The Theory and Measurement of Long-Run Costs (1955), reprinted in G.C. Archibald (ed) _The Theory of the Firm_, Penguin, London, 1971.

3. This method was used by C. Pratten, _Economies of Scale in Manufacturing Industries_, Department of Applied Economics, Occasional Paper, 28, Cambridge, 1971.

levels which are considerably beyond their experience. Nor is it always obvious that "other influences" are being held constant in interview situations.

c) The survivor technique assumes that firms and plants which are increasing their share of industry output over time are of optimal size. It reflects the view that an efficient size of firm is one that meets any and all problems (i.e. survives). The technique avoids the difficult problem of valuing resources properly. For estimates of the potential gains from standardisation, it is perhaps significant that one US study using the survivor method found a wide variation of optimum firm sizes in each industry.[1] In other words, it might be misleading to focus attention on single point estimates of optimum size if actual industry structure reveals a diversity of experience consistent with efficiency and survival. But a critic of the survivor technique has claimed that it is an '... art, not a purely objective scientific process',[2] and that it cannot safely be used on its own. For example, in a study of 117 US industries, the survivor test failed to give clear, unambiguous results for over 60% of the sample.[3] Moreover, a comparison of the evidence from survivor and engineering methods can give completely different orders of magnitude of minimum efficient scale. For example, in the case of cement the

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1. G. Stigler, The Economies of Scale, Journal of Law and Economics, Vol. 1, 1958. Stigler maintains that historical cost valuations are irrelevant under changed conditions. He found that optimum firm size is positively related to both plant size and technology - research (as measured by engineers and chemists per 100 employees).

2. W.G. Shepherd, What Does the Survivor Technique Show About Economies of Scale? Southern Economic Journal, July 1967.

3. Ibid. The technique only indicates efficient sizes and does not provide evidence on the slope and shape of LAC curves.

minimum efficient plant size as a percentage of the industry's output was estimated to be 1.4% using the survivor method and 10% using engineering estimates![1] But are such conflicting and ambiguous results a reflection of the limitations of the empirical work? Or, do they reflect massive actual inefficiencies in industry structure in any set of market conditions? The proponents of the latter view are required to explain why such apparently inefficient firms continue to survive, when markets are competitive and there are alternative suppliers.[2] Of course, some national weapons industries in NATO (e.g. aircraft) are subject to government protection and limitations on competition. In which case, the economic arguments for standardisation can be presented convincingly in terms of the mis-allocation of resources associated with government-created imperfections and restrictions on the operation of a competitive market (e.g. monopoly, entry barriers, tariffs and preferential purchasing).

The evidence from individual industry studies could give a misleading impression that scale economies for a country's manufacturing industry as a whole are more important than is the case on average. After all, if there are major cost reductions from larger scale, why do they remain unexploited? In many instances, the cost penalty of operating below minimum efficient plant size is quite small. At one-third of optimal scale, a cost penalty of under 5% was found in nearly

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1. R. Rees, Optimum Plant Size in UK Industries: Some Survivor Estimates, Economica, Nov. 1973, Table 1; A Silberston, Economies of Scale in Theory and Practice, Economic Journal, (Supplement) March 1972, Table 1.

2. 'If we ask what size firm has minimum costs, and define minimum costs in a sense in which it is in the firms' own interest to achieve it, surely the obvious answer is: firms of existing size ...: foolish questions deserve foolish answers'. M. Friedman, 1955, op. cit.

half of the products studied and of less than 10% for three-quarters of the products.[1] In the circumstances, it has been suggested that given 'the inherent biases of these estimation techniques, no firm conclusion on the relative size of optimal plants for British industry can be reached.'[2] Presumably, such a conclusion is applicable to other nations.

1.4 Size of Firm and Scale Curves: Dynamic Factors

Standard economic theory distinguishes plant and firm level economies as the major sources of cost reductions associated with larger firms. Most of the empirical work is on plant economies. However, in countries such as the UK, increased concentration has resulted more from a rise in the number of plants owned by firms than through increasing plant size.[3] Such developments could be consistent with firm-level economies (alternatively, they could reflect the desire for monopoly power and/or the managerial pursuit of non-profit objectives). A British study concluded that over 70% of the variation in the level of concentration can be explained by scale economies (both plant and firm level economies).[4] But, what little direct evidence there is on firm level economies suggests that they are generally small.

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1. F. Scherer, The Determinants of International Plant Sizes in Six Nations, Review of Economics and Statistics, 1973. The industries with under a 5% cost penalty were cigarettes, paints, oil refining, shoes and automobile storage batteries.

2. S. Aaronovitch and M.C. Sawyer, Big Business, Macmillan, London 1975 p.206.

3. S. Prais, Evaluation of Giant Firms in Britain, N.I.E.S.R., London, 1976, p.46

4. M. Sawyer, Concentration in British Manufacturing Industry, Oxford Economic Papers, Nov. 1971, p.374.

For example, one US study estimated that the economies to a multi-plant firm compared with an efficient single plant enterprise averaged under 2% of unit costs.[1] Other studies show that multi-plant operations tend to be more extensive the larger markets are in relation to the output of a plant of mes, the less steep the slope of the LAC curve and the higher are outbound unit transport costs.[2]

The standard analysis of scale economies is static and it neglects the possible relationship between size of firm and cost-reducing dynamic factors. Technical progress and learning economies are the dynamic sources of lower costs. Supporters of large firms maintain that they promote technical progress. The hypothesis is that only firms which are of large absolute size can afford the costly research and development (R & D) necessary for technical progressiveness.[3] However, a survey of empirical work has concluded: 'The hypothesis that sheer size and a monopolistic-type market structure are sufficient prerequisites of a greater volume of research rests on shaky empirical foundations. It is true that R & D effort is concentrated in large firms, but research intensity appears not to increase significantly with size or the degree of concentration of the market.'[4] There is more convincing empirical support for learning

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1. S. Prais, op.cit., p.65.

2. F. Scherer, Determinants of Multi-Plant Operations in Six Nations and Twelve Industries, Kyklos, 1974, p.137. The elasticity of the number of plants per enterprise with respect to transport costs was 0.39 in 1968: Prais, op. cit., pp.73-74.

3. K. Hartley, Problems of Economic Policy, Allen & Unwin, London, 1977, chp.9.

4. C. Kennedy and A. Thirlwall, Technical Progress: A Survey, Economic Journal, March 1972, p.49.

economies as a source of lower costs. Indeed, some of the cost estimates of (static) scale economies include learning effects.

Learning curves (experience or progress functions) show the extent to which unit costs decline with increases in cumulative output. The basic idea is that the more frequently labour and management perform a specific task, the more efficient they will become at that task. For example, an 80% learning curve is typical for the UK aircraft industry.[1] This indicates that direct labour inputs will decline by 20% for each doubling in the cumulative output of a particular aircraft. For a number of activities (e.g. aircraft, machine tools, turbo-generators, marine diesels, shipbuilding, steel, refrigerators) learning curves with slopes of between 60% and 97% have been observed. Learning varies between industries and, within an industry, between firms and different stages of the production process within the firm. A US study of machine tool production estimated labour learning curves of between 75% and 83%, with a mean slope of 80%. Learning economies were found to be much greater in assembly than in machining operations: assembly gave an average 74% curve compared with 86% for machining.[2] For shipbuilding, learning curves of between 78% and 84% have been estimated. Similarly, in the 1960's, a major British airframe firm found that a 77% learning curve applied to three of its projects. This "composite" curve consisted of a 70% curve for assembly, a 76% curve for detail manufacture and a

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1. K. Hartley, Estimating Military Aircraft Production Outlays, Economic Journal, Dec. 1969.

2. W. Hirsch, Firm Progress Ratios, Econometrica, April 1956, p.139.

92% curve for "other" activities.[1] For the US aircraft industry a 75% learning curve is typical. In other words, there is a diversity of experience and, on *a priori* grounds very little can be said about the magnitude and uniformity of the learning curve. Nevertheless, learning curves for some 50 industries have been identified. On this basis, a general "rule of thumb" has been proposed namely that, '*the characteristic decline in the unit cost of value added is consistently 20% to 30% each time accumulated production is doubled. This decline goes on in time without limit ...*'[2] *Not surprisingly, learning is highly significant in labour-intensive operations*. In addition to learning in production work, there is now evidence of similar economies from experience in R & D. A study of British and American airliners found that firms with previous experience from related military and/or civil work, might complete a project in about 80% of the time required by a manufacturer without such experience.[3] The extent to which learning or previous experience in R & D determines a nation's competitiveness depends on whether technical progress is evolutionary or revolutionary.[4] The possibility

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1. K. Hartley, *op.cit.*, 1969, p.873

2. Boston Consulting Group, reported in Cmnd 7198, *A Review of Monopolies and Mergers Policy*, HMSO, London 1978, p.82. Value-added is wages plus profits. For mass-produced items such as cars and TV's, firms are likely to substitute production planning for learning-on-the-job. C. Pratten, *Economies of Scale in Manufacturing Industry*, Cambridge, 1971, p.283.

3. K. Hartley and W. Corcoran, Time-Cost Trade-Offs for Airliners. *Journal of Industrial Economics*, March 1978, p.218. For example, the Valiant and Boeing B47 and B52 bombers provided previous military experience for the VC-10 and Boeing 707, respectively.

4. K. Hartley, Development Time-Scales for British and American Military Aircraft, *Scottish Journal of Political Economy*, June 1972.

of revolutionary developments will tend to reduce the benefits of previous experience. But, for decision-makers, revolutionary advances are more readily identified *ex post* than *ex ante*. Thus technical progress is an example of the uncertainties which confront decision-makers in the field of weapons procurement policies (including standardisation policies).

B. Method: A Methodology and the Model

1.5 Introduction: The Policy Framework

Standardization is reputed to offer reductions in the unit costs of weapons through a more "efficient" utilisation of NATO's resources currently allocated to defence research and development (R & D) and production. Savings in development resources will emerge if, ceteris paribus, "duplication and overlap" in R & D work is reduced or even abolished. Production costs will also be reduced. Compared with a variety of small-scale outputs, one large production run will lead to scale economies and lower production costs. Moreover, "fixed" R & D costs will be spread over a larger output, so further reducing total unit costs (i.e. R & D and production). Additional gains from standardization are expected if international "collaboration and co-operation" in development and production is associated with the establishment of a free trade area in weapons - i.e. with each member of the Alliance specialising in those parts of the weapons development and production process in which it has a comparative advantage, so reaping the gains from international specialisation and mutually advantageous exchange.

1.6 A Two-Stage Approach

This outline of the sources of costs savings from standardization suggests a two-stage methodology for the industrial survey:

a) Stage I. The identification of the shape of the LAC curve and the minimum efficient size of firm (mes) for each major product within each nation. In particular, we need to obtain an indication of the cost implications of operating below mes. For example, where are European firms in relation to mes? But this evidence will only show the possible cost savings of a greater scale of output within any one nation (i.e. absolute costs). It will not identify which nation within Western Europe is the lowest cost source of supply for any one product.

b) Stage II. The relative position of scale curves between nations has to be determined (i.e. relative costs). Which nations within NATO have a comparative advantage for which weapons? What are the likely cost savings from a NATO free trade area or common market in weapons?

Figure 1.1 summarises our model and methodological approach. Stage I is concerned with movements along a LAC curve, say LAC_1 in Figure 1.1(a). Evidence from industry studies will be presented on the shape of such scale curves within European nations. The cost effects of operating at, say, 50% of mes are of special interest for standardization policy - e.g. C_2 in relation to C_1 in Figure 1.1(a). The advocates of weapons standardization maintain that below mes, C_2 is substantially greater than C_1. Additional to production economies are the potential savings in R & D. These can emerge from two sources, namely, the spreading of "fixed" R & D costs over a larger output as well as possible scale economies in the R & D function. Evidence will be presented on the magnitude of development costs for advanced

technology weapons as well as studies of the relationship between firm size and R & D. Stage II is more ambitious and attempts to identify differences in (and hence the relative positions of) LAC curves between nations - i.e. LAC_1 in relation to LAC_2, as in Figure 1.1(b). For example, at output Q_1 in Figure 1.1(b) nation B is the lower cost supplier and can produce the output at C_1, compared with C_2 for country A: the movement between cost curves is an indicator of comparative advantage. International trade studies as well as international studies of particular industries provide some evidence on comparative advantage. Further insights are available from studies of the effects of tariffs and the estimated benefits of free trade following the formation of the EEC.

Figure 1.1

(a)

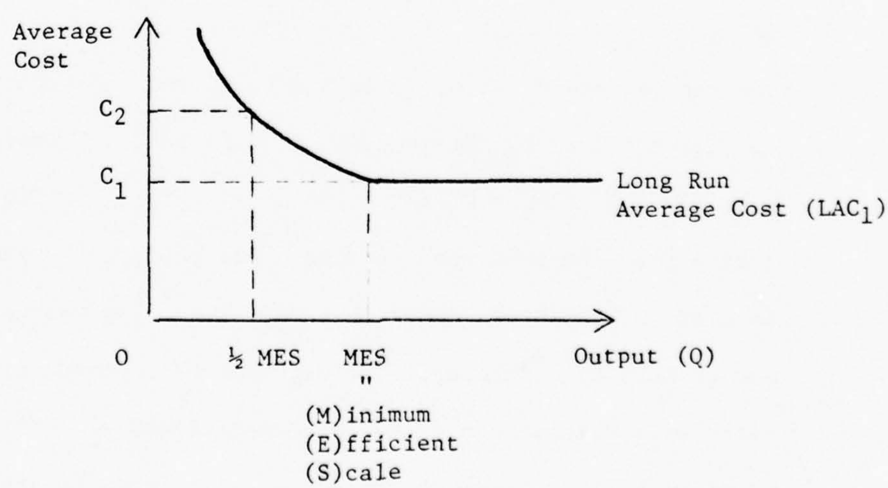
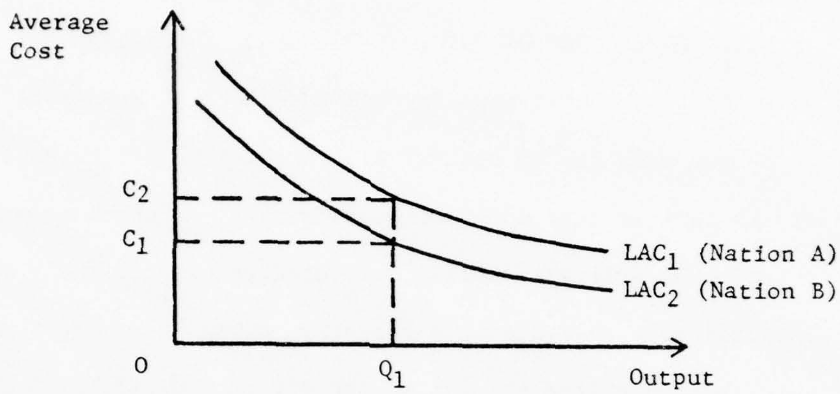
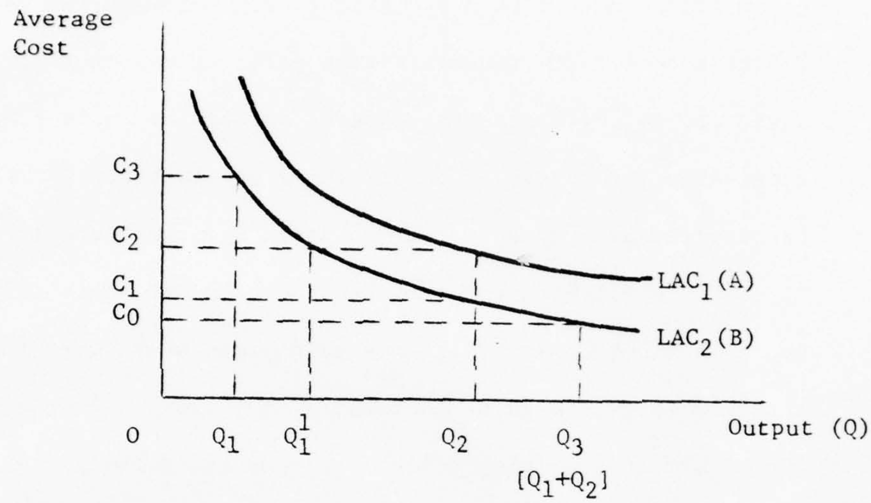


Figure 1.1(b)



This framework can be used to analyse the sources of costs savings from standardization. The possibilities are summarised in Figure 1.2. Consider two nations, with A represented by LAC_1 and B by LAC_2, as in Figure 1.2. Initially, nation A (the USA?) is at the cost-output position C_2 Q_2, whilst country B (UK or France?) is at C_3 Q_1, on LAC_2: then country B is the lower cost supplier and can produce Q_2 at C_1. If B specialises and produces both Q_1 and Q_2, equal to Q_3, its unit costs will be C_0. There are potential cost savings of $C_3 - C_0$ for B and $C_2 - C_0$ for A. Figure 1.2 also shows that under "independence", nation B can achieve the same unit costs as A at output levels lower than Q_2 - i.e. Q_1' gives unit costs of C_2 for country B. International differences in productivity and wage rates will determine a nation's competitiveness. If A's productivity is twice B's but its wage rates are three times as great, then unit costs will be lower in B (i.e. B's unit costs will be two-thirds of A's).

Figure 1.2



1.7 Limitations of the Methodology: Its Assumptions

The methodology outlined above is based on a number of assumptions. These have to be recognised in order to appreciate the limitations of any model used to estimate the potential cost savings from standardization. The major assumptions of the model as reflected in Figures 1.1 and 1.2 are:-

i. Pricing policy for weapons. A full-cost or average cost pricing model is assumed, with weapons prices based on unit costs (including a profit mark-up).[1] In other words, it is assumed that

1. For details of UK weapons pricing policy, see K. Hartley, Estimating Military Aircraft Production Outlays: The British Experience, Economic Journal, Dec. 1969; also, K. Hartley, A Market for Aircraft, Hobart Paper 57, IEA, London 1974.

prices will "follow" the cost curves LAC_1 and LAC_2, as in Figures 1.1 and 1.2. Clearly, the actual pricing policy will depend upon a firm's objectives, the presence or absence of actual or potential competition and the form and extent of government regulation. To the extent that standardization policies restrict competition, there are potential adverse effects through monopoly pricing, especially for spares. For example, consider the UK "belief" that US aircraft are "cheap", but you "pay" for the spares: this is one argument used for an independent UK aerospace industry. The worry about monopoly pricing is reinforced when it is remembered that the estimated gains (to whom?) from standardization also depend upon a nation's pricing policy for recovering its R & D costs on a major weapons system.

ii. The demand or buying side is ignored. All the estimated savings in the model are restricted to the reductions in unit costs as shown in Figures 1.1 and 1.2. Economic theory shows that where markets are imperfect as in defence (monopolies, entry barriers, tariff protection), there is a mis-allocation of resources with adverse effects on consumer welfare. The "best" or optimum allocation of resources can be achieved with a set of competitive markets. Thus an optimum allocation of resources, as reflected in a competitive outcome, represents the maximum savings and benefits which can be achieved from standardization. On this basis all other standardization policies (e.g. off-sets; work-sharing and other departures from competition) are likely to result in smaller savings than the maximum available.

iii. The internal efficiency of firms. Firms are assumed to be technically efficient, with the LAC curves in Figures 1.1 and 1.2 representing cost-minimising behaviour. However, in non-competitive markets, such as defence, enterprises are likely to be characterised by organisational slack or X-inefficiency. Competition acts as a possible self-policing mechanism, inducing firms to minimise costs.[1] If standardization is associated with greater competition in NATO weapons markets, the resulting "shock effect" leading to cost minimising behaviour, will be a further additional source of cost savings. <u>US evidence shows that with scale economies taken into account, competition within a national market can reduce average costs by about 10%.</u>[2]

iv. No dis-economies of scale. However, a major expansion of firm size beyond existing experience levels might encounter managerial dis-economies. This is a particular problem for nations like country B (UK, France?) in Figures 1.1 and 1.2. Will country B follow LAC_2 if output levels of Q_2 and Q_3 were to be feasible? For example, the UK aircraft industry has no experience of US production runs and there might be learning costs for a new entrant into the large-scale league. Moreover, if production is concentrated in a few localised plants, there could be dis-economies in transport and distribution. Any such dis-economies will <u>reduce</u> the estimated cost savings of standardization.

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1. H. Leibenstein, X-Inefficiency Xists - Reply to an Xorcist, <u>American Economic Review</u>, March 1978. Much depends on a supply of entrepreneurs willing to operate at minimum cost.

2. <u>Ibid</u>, p.209.

v. The adjustment period and associated requirement for a re-allocation of resources. To achieve the maximum cost savings from standardization will require a re-allocation of resources to reflect each nation's comparative advantage in weapons development and production. Such a re-allocation will take time and might require the introduction of public policies to "improve" the allocative process, especially in labour markets.[1] Similarly, if standardization concentrates output in a smaller number of firms, an expansion of capacity will be required, with inevitable delays in the delivery of weapons during the adjustment process. The appropriate time-scale for the adjustment period is clearly a matter for public debate. Even with complete agreement between governments on the most desirable form of standardization (!), some 5-10 years is likely to be the minimum time-period.

vi. Ceteris paribus. The model assumes given technology and relative factor prices. But markets are dynamic and not static, especially for weapons. Whilst the future is uncertain, it can be predicted that technology and relative factor prices will change and that these changes will occur both within and between countries. With technical progress and changes in productivity and factor prices, a nation's comparative advantage will change; and these trends will be reflected in market exchange rates. What are the likely trends in the major exchange rates over the next 10-20 years? Within a standardization framework, such questions cannot be ignored, since the

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1. See e.g. K. Hartley, A Market for Aircraft, Hobart Paper 57, IEA, London, p.66, 1974.

answers (forecasts) will clearly affect the "optimal" procurement policies. Standardization policies cannot assume a static world in which today's (or yesterday's) pattern of international comparative advantage and trade flows will necessarily apply in the future. No one can predict accurately the future. The task for policy-makers is to create an environment which allows firms to adapt and adjust to change (e.g. permits new entrants to weapons markets).

vii Other policy targets. Our survey will concentrate on the cost savings of standardization to the relative neglect of the domestic employment, balance of payments and technology implications of standardization. Certainly, the evidence on scale economies indicates substantial opportunities for industrial re-structuring. A UK study of 30 industries found that in 1968 the percentage of total industry employment in plants outside the optimum size range varied between a minimum of 4.9% (margarine) and a maximum of almost 80% (bolts, nuts and screws), with a median of some 33%:[1] an indication of the potential for structural improvement in industries. In some industries and regions, standardization might involve major employment effects. For example, it has been estimated that the adoption of a competitive policy for the British aircraft industry could result in the "loss" of 50,000-100,000 jobs.[2] But such estimates have to be placed in their macro-economic context. Here, general evidence on the employment effects of increased imports is relevant. Whilst increased imports might have

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1. R. Rees, Optimum Plant Size in the UK, Economica Nov. 1973, Table 1.

2. K. Hartley, A Market for Aircraft, op. cit., p.66.

serious local or industry-specific effects, the evidence shows that, in general, their total impact on employment in developed nations is small in relation to total employment (or to job quits). US studies found that in 1969, some 77,000 jobs were lost for every $1 billion of imports (1969 prices) - this was 0.1% of 1969 civilian employment and 3% of imports.[1] A further American study of 1960-65 found that increased imports were relatively unimportant as a factor accounting for the total change in employment - the negative effects of productivity increases and the positive impact of demand increases were much more important, as shown in Table 1.1.

Table 1.1 Employment and Imports

Change in employment (000's) attributable to:	Numbers (000's)	% of jobs "lost"
Demand	+ 5,339.7	
Imports	- 234.4	5.1%
Output per employee (productivity 1957-59 = 100)	- 3,256.9	70.9%
Interaction	- 1,100.1	23.9%
Employment:	+ 1,105.3	

Notes (i) All manufacturing, 425 industries, USA, 1960-65.
(ii) Source: C. Hsich, International Labour Review, 1973, op.cit

1. C. Hsich, Measuring the Effects of Trade Expansion on Employment: A Review of Some Recent Research, International Labour Review, Jan. 1973.

Even the local and industry employment effects of increased imports can be exaggerated. For example, between 1951 and 1966 with import competition, employment in the UK Lancashire cotton textile industry fell by 215,000 workers, or 60%. The labour force re-adjusted through outward migration and greater diversification of industry in Lancashire (regional policy): between 1955 and 1964, unemployment in the textile areas was close to the national average.[1] In other words, labour markets can, and do, adapt and adjust to change. For our purposes we need to recognise that there are employment, as well as balance of payments and technology implications of standardization policies and each of these might be major elements in a government's objective function.

1.8 Conclusion: The Application of the Model

This model provides a framework for quantifying the cost savings from standardization in weapons procurement. The concept and measurement of scale economies and the assumptions of the model have been specified. Given these qualifications, the following sections will show how the available data from industrial and international studies can be used to provide some empirical content for the model. Do published studies show the potential range of cost savings? Whilst some broad generalisations are possible, it will be seen that in many instances, detailed economic studies of cost conditions in weapons industries are conspicuously absent. In such circumstances,

1. *Ibid*.

a major contribution of our survey will be the identification of potential research areas. After all, a policy initiative such as standardization requires some analytical and empirical support. Evidence from related non-defence industries can be used to provide "educated guesses" on cost savings. But, informed guesses are not perfect substitutes for research studies directed at specific defence industries. A major contribution of our survey will be the identification of data deficiencies - i.e. the listing of what is NOT known and what should be known to answer questions about the likely magnitude of cost savings from standardization.

Chapter 2

Industrial Cost-Quantity Studies: The U.K. and W. Europe

2.1 Introduction

This chapter reports on the available evidence on scale economies in the U.K. and Western Europe, concentrating on cost-output relationships and minimum efficient scale (mes). Studies of international competitiveness are also presented as an indication of the potential gains from possible free trade variants of standardization policies.

The chapter begins with a specification of the data required for our study, followed by a brief statement of the limitations of the evidence. A detailed account is provided of scale economies in the U.K., mainly because compared with other European nations, Britain is especially well-documented. And, in the absence of European data, the U.K. will be taken as representative of Western Europe as a whole. After considering European evidence, the magnitude of the gains from free trade will be assessed. Comparisons are made between Western Europe and the U.S.A.

2.2 The Data Requirements

Table 2.1 summarises our "ideal" data requirements for a study of the cost savings of weapons standardization policies. Ideally, data are required on actual output in relation to mes for each category of weapon and the cost implications of departing from mes (Tables 2.2 and 2.3 are good examples of what is needed). Predictably, published data are not available for each of the items shown in Table 2.1. Nevertheless, we can obtain cost-quantity information for most of the broad groups - i.e. aerospace and guided weapons, electronics, shipbuilding, motor vehicles, engineering and some of the "others" (clothing, turbo-generators). In many instances, our cost estimates can be criticised because of massive aggregation. For example, cars and heavy commercial vehicles are taken as typical of military vehicles as a group; similarly, aerospace and guided weapons have to be combined and treated as one broad group.

Table 2.1 Ideal Requirements

1. **Aerospace**

    1.1 Combat aircraft
    1.2 Maritime, transport, training aircraft
    1.3 Nav/attack and other sub-systems
    1.4 Engines
    1.5 Helicopters
    1.6 Hovercraft

2. **Shipbuilding/Marine Engineering**

    2.1 Warships
    2.2 Patrol and small craft
    2.3 Sensor and fire control systems
    2.4 Propulsion units
    2.5 Fleet support vessels
    2.6

3. **Vehicles**

    3.1 Tanks
    3.2 Armoured Fighting Vehicles: (MICVs etc.)
    3.3 'B' vehicles (trucks etc.)
    3.4 Cars
    3.5 Self-propelled Artillery
    3.6

4. **Guided Weapons**

    4.1 Air-launched A/A, A/S
    4.2 Sea-launched S/A S/S
    4.3 Ground (and submarine) launched 'large' missiles
    4.4 Ground-launched 'small' missiles
    4.5 Special target acquisition/designation systems
    4.6

5. <u>Ordnance/Arms</u>

5.1 Artillery weapons
5.2 Small arms and Mortars
5.3 Ammunition
5.4 Torpedoes, Mines etc.
5.5

6. <u>Electronics n.e.s.</u>

6.1 Signals, telecommunications
6.2 Fire Control Systems
6.3 ADP Systems
6.4 Sensors n.e.s.
6.5

7. <u>Engineering</u>

7.1 Combat engineer equipment
7.2 Aircraft ground support equipment
7.3
7.4
7.5

8. <u>Other</u>

8.1 Clothing
8.2 Batteries
8.3 Turbo-generators

2.3 Limitations of the Evidence

The available evidence on scale economies, both nationally and internationally, encounters some common problems. These are:

i. Data. Statistics are more reliable, more available and more comparable between the UK and USA. European data are less available and more deficient. For example, a 1970 international study of chemicals on a sector basis in the UK, West Germany and the USA could only be undertaken for the USA and the UK - and this was only possible for firms and not for plants, using 1963 census data.[1] There are also international differences in the definition of an industry - e.g. for steel, the industry definitions for the U.K. are much wider than for the EEC.[2] Finally, even within a country, census definitions change over time and often include more than one market or industry.

ii. Firms, especially in the private sector, are frequently multi-product units (rather than single product units) with varying degrees of vertical integration. Thus, concentration on a firm's weapons activity might give a misleading impression of sub-optimal output (i.e. less than mes). The enterprise might have related civil production for home and export markets which could mean that it is actually obtaining most of the worthwhile

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1. D. Burn and B. Epstein, Realities of Free Trade: Two Industry Studies, Allen and Unwin, London, 1972, p.223.

2. A. Cockerill, The Steel Industry: International Comparisons of Industrial Structure and Performance, Cambridge, Department of Applied Economics, Occasional Paper 42, 1974, p.31.

scale economies. It is also possible that firms which <u>appear</u> to be of less than minimum efficient scale might still compete if they can purchase components from specialist suppliers[1] with long production runs able to obtain all the economies of scale. On this basis, there is a danger of over-estimating the cost reductions from a greater output - the survival of a private firm suggests that it might be of the "correct" size.

iii. Firms in an industry do not produce an homogeneous product and this causes further problems in estimating scale curves and undertaking international comparisons. For example, the UK car industry consists of firms producing small to large cars in the low to high price range (e.g. Minis and Rolls Royces).

iv. Measuring output and size of firm. Money measures of output might reflect monopoly power. Also, international differences in the factor "mix" are not revealed when the size of firm is measured by employment.

v. Engineering estimates of minimum efficient scale do not normally identify the minimum cost point: they normally locate a size beyond which a further increase in output, say a doubling, will lead to a relatively small fall in unit costs of under 5%.

vi. The best technique for any one nation depends partly on its relative factor prices. Assumptions about factor prices are required for undertaking international comparisons. Moreover,

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1. In the UK car industry, up to 50% of a part or component consists of a standard "base or core" to which is added the special requirements of each customer.

it has to be recognised that standardization policies might change relative factor prices within NATO!

vii. International comparisons of scale curves are further complicated by differences in accounting conventions for valuing assets, differences in the age of capital and variations in the skills of the labour force (human capital).

viii. Price data can be a misleading indicator of international competitiveness. Secret discounts can be offered, whilst the "average" price of a product reflects an industry's mix of domestic and export sales. Further complications arise because of differences in the product "mix" between nations - e.g. if the U.K. exports Rolls Royce cars, it will appear to be a higher price source of supply compared with a nation which exports small, cheap vehicles.

2.4 UK Evidence on Scale Economies

Most of the available British evidence on scale economies - covering about one-third of manufacturing industry - is summarised in Tables 2.2 and 2.3. This evidence relates to technical economies of scale defined broadly to include learning effects and the economies from spreading both initial and development costs over a greater output. Once other sources of economies and dis-economies are considered (i.e. firm economies), it is most likely that the estimates of technical economies in Tables 2.2 and 2.3 will under-estimate rather than over-estimate the importance of scale economies. For example, a study of the UK

machine tool industry found that large firms might gain buying economies of scale equivalent to $2\frac{1}{2}\%$ - 5% savings in unit costs.[1] Nevertheless, technical economies tend to be dominant.

1. C. Pratten, Economies of Scale for Machine Tool Production, Journal of Industrial Economics, April 1971, p.164.

Table 2.2 Estimates of Minimum Efficient Plant Scale, UK

Industry	Minimum efficient plant scale (MES) Absolute Output, p.a.	MES as % of UK output (%)
I. ENGINEERING		
1. Aircraft	BAC 1-11 type airliner: > 50 aircraft	100 + (R & D = 33% of net output, 1968)
2. Bicycles	160,000 units	8
3. Domestic Electrical Appliances:		
a) Range of 10 appliances	500,000 units	20
b) Electric cookers	300,000 units	30
c) Electric refrigerators	250,000 - 800,000 units	22 - 69
d) T.V. Tubes	750,000 - 1.5 million units	100
4. Electronic Capital Goods:		
a) Range of products	Output of £200m (1969 prices)	100 (R & D = 17% of net output, 1968)
b) One product (e.g. radar)	1,000 units	100
c) Electronic calculators	3-4 million units	100+
d) Computers	1,000 units or 10% of world market	100
5. Machine Tools	300 employees	100+ (R & D = 4% of net output, 1968)
6. Motor Vehicles:		
a) Cars	½ - 1 million units	29-57 (R & D = 4% of net output, 1968)
b) Heavy commercial vehicles	20,000 - 30,00 units	5 - 7
c) Tractors	90,000 units	76
d) Clutch mechanisms	300,000 units	12
e) Automobile storage batteries	1 million units	14
f) Rubber tyres	5,000 tyres per day	6
g) Anti-friction bearings	800 employees	2

	Industry	Minimum efficient plant scale (MES) Absolute Output, p.a.	MES as % of UK output (%)
7.	Motors:		
	a) Electric motors	£10m (1969 prices)	60
b	b) Industrial diesel engines	100,000 units	56 (R & D = 6% of net output, 1968
	c) Large marine diesel engines	100,000 h.p. per annum	10
8.	Turbo-Generators	4 p.a.; 8 G.W., p.a.	100 + (R & D = 5% of net output, 1968)
9.	Transformers	10,000 MA, p.a.	n.a.
II	<u>PROCESS INDUSTRIES</u>		
1.	Bread	12-30 sacks per hour	½ - 1
2.	Brewing	1 - 4½ million barrels, p.a.	3 - 13
3.	Bricks	25 million	0.5
4.	Cement	1.2 - 2 million tons	7 - 11
5.	Chemicals:		
	a) Ethylene plant	300,000 tons	34 (R & D = 5% of net output in 1968)
	b) Sulphuric acid	1 million tons	30
	c) Ammonium nitrate	300,000 - 350,000 tons	27 - 31
6.	Synthetic rubber	100,000 tons	25 (?)
7.	Detergents	70,000 tons	20
8.	Iron and Steel:		
	a) Steel	2 - 9 million tons	8 - 37
	b) Pig iron	2 - 3 million tons	13 - 20
	c) Iron castings	50,000 tons (cylinder blocks)	1
	d) Aluminium semi-manufactures	200,000 tons	36
9.	Oil Refining	10 million tons	10 (R & D = 8% of net output 1968)

Industry	Minimum efficient plant scale (MES) Absolute Output, p.a.	MES as % of UK output (%)
III TEXTILES & CLOTHING		
1. Cotton and synthetic textiles	37.5 million square yards	6
2. Synthetic fibres	80,000 tons (polymer)	18
3. Footwear	1,200 pairs per day	0.2
4. Wool textiles	20% reduction in the number of mills	n.a.
IV OTHER INDUSTRIES		
1. Books	100,000 (paperback)	n.a.
2. Cigarettes	36 billion	2.1
3. Glass beer bottles	133,000 tons	n.a.
4. Plasterboard	18-20 million square metres	17 - 19

Sources: 1. C. Pratten, Economics of Scale in Manufacturing Industry, Department of Applied Economics, Cambridge, 1971.

2. Cmnd 7198, A Review of Monopolies and Mergers Policy, HMSO, London, 1978, pp.87-88.

Notes: 1. The data were collected between the mid-1960's and early 1970's - most refer to the second half of the 1960's.

2. Data based on engineering estimates.

3. G.W. = Gigawatts; MA = megavolt-amperes

4. n.a. = data not available

5. UK output figures are based on 1973.

Table 2.3 The Slope of Scale Curves, UK

Industry	Percentage increase in costs per unit at 50% mes compared with costs at mes: Unit Costs (%)	Value added per unit (%)	Type of Industry	mes as % of UK output
I Unit Cost Increases of 20% or more				
1. Books (hardback)	36	50	O	n.a.
2. Bricks	25	30	P	0.5
3. Dyes	22	44	P	100
4. Newspaper	>20	>40	O	30
5. Aircraft (airliner of BAC 1-11 type)	>20	>25	E	100+
Mean (1-5)	(25)			
II Unit Cost Increases of 10%-19%				
1. Bread	15	30	P	1
2. Electric Motors	15	20	E	60
3. Iron Castings (cylinder blocks)	10	15	P	1
Mean (1-3)	(12)			
III Unit Cost Increases of 5-9%				
1. Beer	9	55	P	3
2. Chemicals	9	30	P	27-31
3. Cement	9	17	P	10
4. Marine Diesel Engins	8	15	E	10
5. Electronic Capital Goods (e.g. radar; computers)	8	13	E	100
6. Domestic Electrical Appliances	8	12	E	20
7. Motor Cars	6	10	E	29-57
8. Steel	5-10	12-17	P	8-37
9. Oil Refining	5	27	P	10
10. Synthetic Fibres	5	23	O	18
11. Iron Foundry (small castings)	5	10	P	0.2
12. Turbo-Generators	5	10	E	100+
13. Machine Tools	5	10	E	100+
Mean (1-13)	(7)			

Industry	Unit Costs (%)	Value added per unit (%)	Type of Industry	mes as % of UK output
IV <u>Unit Cost Increases of Under 5%</u>				
1. Diesel Engines	4	10	E	56
2. Detergents	2.5	20	P	20
3. Footwear	2	5	T	0.2
4. Sulphuric Acid	1	19	P	30
5. Plastic products (range)	small increase in costs			
Mean (1-5)	(2.4)			
ALL INDUSTRIES: MEAN (I-IV)	10.48			
MEDIAN (I-IV)	8.0			

Source: C. Pratten, *op. cit.*

Note: E = engineering;
P = process;
T = textile and clothing
O = other industries

Table 2.2 distinguishes four groups of industries, namely, engineering, process, textile and clothing and "others". Very few of the industries are wholly in the defence sector, with the exception of aircraft and electronics. In the circumstances, there are five alternative "guidelines" for assessing the potential cost savings of standardization policies:

i. "All manufacturing industries" could be considered as typical of the UK defence industries as a group. Table 2.3 shows that by operating at minimum efficient scale (mes) compared with 50% of mes, unit costs can be reduced by about 10%:[1] a figure which is consistent with other international studies of scale curves.[2]

ii. The engineering sector only could be taken as typical of the defence industries. Table 2.3 indicates that the unit cost savings of doubling output to mes approach 8-9%. (mean = 9%; median = 8%)

iii. The few industries shown in Table 2.3 which are directly involved in defence could be taken as typical of the defence industries. For aircraft and electronics, the unit cost savings of doubling output to mes might average some 14% (Table 2.3).

iv. The industries where mes is 100% or more of the UK market could be typical of the defence sector. On this basis, the unit cost

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1. Strictly at 50% of mes if unit costs are 110, then the cost savings of operating at mes are 10/100 x 100 = 9%.

2. F. Scherer, The Determinants of International Plant Sizes, Review of Economics and Statistics, 1973.

savings of doubling output to <u>mes</u> are in the region of 8-12%. (Table 2.3: mean = 12% median = 8%).

v. The cost data in Table 2.3 could be applied to the broad defence industry groupings in Table 2.1. On this basis, the unit cost effects of operating at 50% of <u>mes</u> for the items in Table 2.1 are:

		(%)
Aerospace and guided weapons		>20
Shipbuilding[1]		10
Vehicles (cars)		6
Ordnance and arms		10
Electronics		8
Engineering (average for group)		9
Others - turbo generators		5
- clothing: footwear		2
synthetic fibres		5
	Mean	8.3
	Median	8

These estimates suggest that if defence industries are operating at 50% of <u>mes</u>, there are potential cost savings of between 8% and 14% from operating at <u>mes</u>. <u>From this evidence, a figure in the region of 10% for the reduction in unit costs seems a reasonable "rule of thumb" when output is doubled from 50% of mes</u>. Three qualifications are important. First, data are not published on the output of defence industries in relation to <u>their mes</u>: if defence firms are operating at less than 50% of <u>mes</u>, the potential reductions in unit costs from operating at <u>mes</u>, are likely to be much greater

1. Shipbuilding is not shown in Table 2.3, but the estimate is based on an 80% learning curve converted to a 90% unit production cost curve (for each doubling in output). Ordnance and arms data are not available, so we have assumed that the sector is typical of the whole group shown in Table 2.3 (average).

(due to the steepness of the scale curve at low outputs). Second, it has to be remembered that *mes* is *not* the minimum cost point. A further doubling in scale for firms already at *mes* will reduce unit costs by up to 5% (technical economies only). Third, an average saving of 10% does not allow for the relative weightings of different defence expenditures. It is simply an average of percentage savings. However, once the various percentage unit cost savings are applied to each category of defence expenditure, the results are changed considerably. Table 2.4 gives a simple example. The effect of assuming that both aircraft and clothing have the same cost savings can be compared with a situation where they have different cost savings, even though the average remains 10% (15+5÷2).

Table 2.4 Example

	Expenditure	10% cost saving	15% cost saving	5% cost saving
Aircraft	100	10	15	
Clothing	10	1	-	0.5
Total	110	11	15	0.5
Cost Saving		10%	14%	

The evidence permits some further generalisations about scale economies and the characteristics of the industries where such economies are likely to be present:

i. In engineering industries, substantial economies arise from spreading the "fixed costs" of developing a new product and "starting-up", from learning and from the introduction of more efficient techniques (e.g. capital-intensive methods).

ii. For process industries, such as chemicals, there are economies from the less than proportional increase in the external dimensions of plant as scale rises: this reduces capital costs per unit of capacity. In this context, there is some support for the "0.6 rule" ($\pm$ 0.2) as a rough working hypothesis - i.e. a 1% increase in capacity will raise capital costs by 0.6%.[1]

iii. Economies of scale for labour costs have been found to be much greater than for total unit costs of production.[2] An indication of this can be seen in Table 2.3, which shows data on the percentage increase in value-added as well as unit costs, at 50% of mes.[3]

iv. It has been hypothesised that manufacturers of small equipment probably come closer to achieving maximum potential scale economies (i.e. mes) than do manufacturers of large equipment.[4]

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1. J. Haldi and D. Whitcomb, Economies of Scale in Industrial Plants, Journal of Political Economy, 1967.

2. C. Pratten, op. cit., p.282.

3. Value-added (VA) is wages plus profits. It can be estimated by dividing the percentage increase in unit costs by the percentage rise in value-added - i.e. VA = $\Delta TC \div \Delta VA$, as shown in Table 2.3. The cost of materials and bought-out parts is usually 50% or more of total costs: the value-added column in Table 2.3 shows the effects of scale on labour and capital inputs only.

4. G. Haldi and D. Whitcomb, op. cit.

v. The R & D intensive industries are most likely to be the ones with the greatest opportunities of obtaining any available economies from the spreading of R & D expenditures. In 1968, the UK sectors where R.& D as a percentage of net output exceeded the national average were aerospace electronics, oil refining, diesel engines, chemicals, man-made fibres, electric motors and generators, motor vehicles and machine tools (Table 2.2). Significantly, some of these were industries where the mes was 100% or more of UK output.

vi. It is quite likely that the range of output over which scale economies apply and the magnitude of such economies are increasing over time - e.g. in cars, the UK mes for final assembly has risen from 100,000 units per year in the 1950's to some 250,000 units p.a. in the mid-1970's. Since many of the estimates in Tables 2.2 and 2.3 are based on 1960's technology, they could understate the significance of scale economies in the UK (and elsewhere).

2.5 UK Evidence on Concentration and Scale Economies

Data on concentration can provide some indirect evidence on scale economies. We have already reported that economies of scale explain a large proportion of the variations in concentration in the UK.[1] Further evidence shows a positive relationship between a firm's market share for a product and its unit cost advantage over smaller rivals.

1. M. Sawyer, op. cit., 1971.

The relationship is shown in Table 2.5, where it can be seen that compared with their smaller rivals, firms with over 40% of the market had a unit cost advantage of some 10%. This is a further indication of the possible cost savings of standardization policies, although the estimate is less than the figure obtained from studies of mes.

Table 2.5 Market Shares and Unit Costs

Market share (%)	Unit cost advantage relative to firms with less than 10% market share (%)
Under 10%	-
10 - 20	3.5
20 - 30	4.3
30 - 40	7.2
Over 40	9.8

Source: Cmnd 7198, A Review of Monopolies and Mergers Policy, HMSO, London, 1978, p.90.

Elsewhere, a U.K. study of highly-concentrated products found that scale economies were listed as a substantial barrier to new entrants in about one-third of the sample.[1] The relevant industries included ball bearings, cars, sheet steel, synthetic rubber, wheeled tractors, flat and safety glass, together with manufactured fuels and tinplate. Technical knowledge and R & D

1. G. Walshe, Recent Trends in Monopoly in Great Britain, Cambridge U.P., 1974, pp. 112-113. The sample was n = 32 products.

expenditure also acted as substantial entry barriers for crawler tractors, line apparatus, telegraph and telephone installations and for data processing equipment. In total, scale economies and technical knowledge plus R & D expenditures were listed as entry barriers for some 70% of the sample. In the absence of "better" evidence, data on concentration can provide some broad indications of the extent of scale economies in an industry.[1] Studies of mergers are also relevant, especially if standardization policies involve the creation of larger (international?) firms. For the UK, there is not much support for the hypothesis that take-overs result in improved efficiency. One study of over 200 UK mergers (1964-72) concluded that "In general, a mild decline in profitability did typify these mergers - if market power was typically unchanged as a result of the merger, the profitability decline reflects a fall in efficiency. And if, as seems plausible, market power was more often enhanced by merger, then the profitability decline is likely to understate the loss in efficiency".[2] There is also some evidence that mergers encounter managerial diseconomies and that bigger plants have worse strike records and enjoy a less favourable utilization of their labour force due to absenteeism and sickness.[3] In other words, even where mergers lead to scale economies, the advantages might be more than offset by less competition and other

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1. See also the various industry reports of the Monopolies and Mergers Commission.

2. G. Meeks, Gains From Merger, Department of Applied Economics, Occasional Paper 51, Cambridge, 1977, p.25.

3. Ibid, p.31.

dis-economies, resulting in higher prices and a mis-allocation of resources. Standardization policies involving mergers cannot ignore such evidence.

2.6 Scale Economies in Western Europe.

The EEC has argued that large European firms are required to obtain scale economies in production and in R & D. Much has been made of the marked size and productivity differences between the largest European firms and their US rivals. However, there are few published English language studies of the extent of scale economies and minimum efficient scale (mes) by individual industries in each of the European nations.[1] In the circumstances, and in the absence of alternative evidence, the UK data on scale curves and mes can be taken as typical of the whole of Western Europe. There is support for such a generalisation. (see also chp.3, Steel Industry). A study of scale economies in France, W. Germany, Sweden, the UK, USA and Canada, concluded that there is "... little divergence among the views of producers in the six nations with respect to basic process optima, nor did perceived limits on the size of plants which could be managed successfully vary much between nations for a given product mix. Interviewees who had thought about the problem exhibited remarkable unanimity in their estimates of the minimum cost plant size ..."[2]

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1. See e.g. A. Jacqueman and H. de Jong, European Industrial Organisation, Macmillan, London, 1975.

2. F. Scherer, et al, The Economics of Multi-Plant Operation, Harvard U.P., 1975, p.81. See also B. Klotz, Scale Economies and Learning Curves (this report)

Admittedly, wide variations exist in the size of plants actually chosen, but these are generally explained by identifiable market characteristics. Moreover, in the weaving, glass bottle and bearing industries, there is evidence of managerial dis-economies - i.e. beyond a critical size, managers can no longer cope and unit costs rise[1] (with possible implications for some forms of standardization policies).

Whilst estimates of mes appear similar for given industries in NATO, it is possible that countries will be at different points on the scale curve, so displaying varying opportunities for cost reductions via larger outputs. Some indication of the extent to which the UK and European nations are actually exploiting available scale economies can be obtained from the data on average firm and plant sizes and concentration ratios. Larger plants and bigger firms indicate scale economies whilst we have already suggested that such economies also explain higher concentration ratios. Compared with several European countries, Britain has relatively more large enterprises (i.e. employing over 40,000). In France and Germany, giant enterprises occur only about half as frequently as in Britain or the USA.[2] Typically, the largest firms are in industries such as cars, chemicals and electrical equipment. Table 2.6 shows the largest manufacturing enterprises in each nation for 1972: note that the largest American firm is twice the size of the largest European unit.

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1. Ibid, p.84.

2. S. Prais, Giant Firms in Britain, NIESR, London, 1976, p.156.

Table 2.6

Country	Name of Firm	Product	Employment (000's)
Belgium	Solvay	Chemicals	45
France	Renault	Cars	157
Germany	Siemens	Electrical equipment	301
Italy	Fiat	Cars	189
Netherlands	Philips	Electrical equipment	371
Sweden	Ericsson	Telecommunications	71
Switzerland	Nestle	Food	116
UK	General Electric	Electrical equipment	211
USA	General Motors	Cars	760

Source: S. Prais, op. cit., p.223f.

A recent study of industry in EEC, reported on the average size of the four largest enterprises in 41 industries. It found that UK firms are larger than German ones in 29 of the 41 industries, larger than French ones in 37 industries and larger than Italian ones in 40 industries.[1] Although published in 1975, the study had to use 1963 data! It was also found that, in general, the level of concentration is very similar in Germany, France and Italy (4-firm concentration ratios of 20-24%) but substantially higher in the UK (32%).[2] Finally,

1. K. George and T. Ward, The Structure of Industry in EEC, Department of Applied Economics, Cambridge, Occasional Paper 43, 1975, p.23.

2. Ibid, p.17. A wide range of concentration ratios might be compatible with constant costs and firms operating at mes. International comparisons show that the ranking of industries by concentration levels tends to be similar - i.e. high concentration industries in one country tend to be high concentration industries in another.

average plant sizes are about the same in Germany as in the USA, slightly smaller in the UK and considerably smaller in France, Sweden and Italy - some of the evidence is presented in Table 2.7.

Table 2.7 Plant Sizes

Nation	Index of Median Plant Size
USA	100
W. Germany	97
UK	79
France	37
Sweden	16

Source: Scherer, *et al*, *op. cit*. p.65.

Note: Data show average sizes of largest 20 plants in a set of industries for each nation, with US = 100 for the average size of the top 20 US plants in similar industries.

On the basis of the above evidence on concentration ratios, plant and firm size, it seems reasonable to regard the UK experience with scale curves as fairly typical of European nations. *In other words, the opportunities for exploiting scale economies are likely to be similar between the UK and Europe as a whole.* If anything, most European nations operate at a smaller scale than the UK, so that in these countries *greater* cost savings are likely to be available

from larger outputs.[1] So far, we have analysed the shape of scale curves and movements along these curves. Our model also showed that further gains could arise if there are differences in the relative positions of long-run average cost curves. Nations can gain from specialisation and international trade on the basis of comparative advantage. These gains are likely if standardization policies create a competitive market and free trade area in weapons within NATO. This source of potential gains must now be considered.

1. Interestingly, for 1967, some 50% of US industrial output was estimated to be in plants of less than mes. The majority of plants in most US industries are suboptimal in scale: a crude indicator of the opportunities available, even in the USA, for obtaining further scale economies. L. Weiss, Optimal Plant Size and the Extent of Suboptimal Capacity, in R. Masson and P. Qualls (eds.), Essays on Industrial Organisation in Honor of Joe S. Bain, Ballinger, Mass., 1976.

2.7 Comparative Advantage and the Gains From Trade: International Competitiveness

2.7 (i) Introduction

There is such a considerable theoretical and empirical literature on this subject that it merits a separate study. Within our terms of reference, we can only outline a broad methodology and review some of the more general evidence. The treatment must necessarily be superficial. Three questions arise. First, how can a nation's competitiveness be measured? Second, what is the general evidence on competitiveness, including international differences in productivity? Third, what are the likely gains from a free trade area in weapons?

2.7 (ii) Methodology: some measures of comparative advantage

Efforts to measure comparative advantage encounter a series of difficulties.[1] For international comparisons are we comparing identical products? Consider, for example, the type of cars produced (e.g. size and H.P.) in Europe and the USA, as well as the "mix" of car output by size ranges and price, as well as the proportion of commercial vehicles in total output. Such problems cannot be avoided in international studies of differences in labour productivity by industry.[2] Difficulties also arise when price data are used to measure

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1. See also chapter 2, section 2.3

2. United Nations, Methodological Problems of International Comparison of Levels of Labour Productivity in Industry, Conference of European Statisticians, No.21, New York, 1971.

international competitiveness. Prices can be "distorted" (in relation to costs) by tariffs and freight charges, by any price discrimination between home and export markets and by the fact that the prevailing exchange rate might not be in equilibrium. In view of these problems of assessing comparative advantage, only large differences in indicators of international competitiveness for a given product, together with persistent differences in trends between competitor countries, should be used as reliable (but not precise) guides to comparative performance.

One feature of the exchange rate problem is of major importance to weapons standardization policies. When making international comparisons of expenditure on research and development (R & D), official exchange rates are inappropriate - i.e. official exchange rates reflect traded goods, but R & D is remote from trade. Thus, international comparisons of national R & D expenditures require the construction of special exchange rates for R & D. The results are dramatic. A study of 16 nations found that, in all but two cases, official exchange rates appear to be inaccurate proxies for R & D exchange rates.[1] The British-American R & D exchange rate was estimated to be £1 = $4.76 at a time when the official rate was £1 = $2.8 (1963-64)! From the UK viewpoint, the official rate understated the cost of American R & D or, from the US point of view, overstated the cost of British R & D.[2] Other studies

1. A. Macdonald, Exchange Rates for National Expenditure on R & D, Economic Journal, June 1973.

2. The UK will believe that a project costing £100 for R & D will cost $280 in the USA when, in fact, the true cost is $476. Similarly, the USA will expect R & D work costing $280 to cost £100 in the UK - in reality the UK cost will be £59!

have shown similar results.[1] For British and American military aircraft, the R & D exchange rate was estimated at £1 = $5.5 in the 1960's. A comparison of F111 and TSR-2 using this R & D exchange rate concluded that if the TSR-2 had been developed in the USA, the "effort" would have been similar to the UK effort but, at the official exchange rate (£1 = $2.8), the actual cost would have been twice as great.[2] There are two implications for weapons standardization policies. First, when official exchange rates are used for international comparisons of R & D, they are likely to distort and misrepresent the value of the real resources employed in R & D in the various countries. Second, for weapons manufacture, international specialisation based on comparative advantage might require that R & D and production work be allocated to different nations. For example, the UK, or France might have a comparative advantage in aircraft R & D (or parts of R & D), and the USA a relative advantage in production (and in flight-testing). However, it is recognised that for a given weapon such an international division between development and production work is not costless (e.g. costs of transferring technology from developer to producer nation).

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1. OECD, Gaps in Technology: Analytical Report, Paris, 1970, p.116. This Report suggested that a $ spent on R & D generally in the UK would be equivalent to about $1.75 spent in the USA; hence an R & D exchange rate of £1 = $4.9 (official rate £1 = $2.8). A recent UK study stated that for pharmaceuticals R & D, a $ spent in UK equalled $2.5 - $2.75 spent in the USA, giving an R & D exchange rate of £1 = $4.75 - $5.25 in the mid-1970's (official rate £1 = 1.9): Chemicals EDC, Innovative Activity in Pharmaceuticals, NEDO, London, 1973, p.8. This same study concluded that once allowance is made for cost differentials, the yield of pharmaceutical R & D man for man becomes comparable in the UK and the USA (i.e. similar efficiency). Ibid p.25.

2. Royal Aeronautical Society Working Party, Effectiveness in R & D, London, 1969, Part II, p.36.

Once these issues are recognised, how can we measure comparative advantage? Various indicators are used to measure a nations comparative advantage and hence its competitiveness. There are at least five possibilities:

a) A nation's export performance by product groups (levels, trends and relative shares). Here, a popular indicator is whether a nation's share in world manufacturing exports is rising or falling.[1] The economic "logic" of such an index is simple. Nations with higher efficiency levels in a given industry relative to industry in general, will register higher export sales for that industry than their relatively less efficient competitors - i.e. the theory of relative advantage suggests a connection between industrial efficiency and trade performance. In other words, the hypothesis is that costs determine prices and prices determine international trade advantage - and evidence suggests that consumer prices are negatively correlated with export market shares.[2] This export indicator of competitiveness has been applied to the Latin American weapons market. In recent years, European weapons suppliers have been increasing their sales to Latin America at the expense of the USA - e.g. aircraft, missiles, warships, and tanks.[3]

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1. R. Cooper and K. Hartley, Export Performance and the Pressure of Demand, Allen and Unwin, London, 1970.

2. H. Glejser, Empirical Evidence on Comparative Cost Theory from the EEC, European Economic Review, 3, 1972.

3. L. Einaudi, et al, Arms Transfers to Latin America, Rand, R-1173, 1973.

b) The trend of imports into a nation's domestic markets.[1]

c) The level of tariff protection. High tariff rates indicate a lack of competitiveness. For example, in the late 1950's, for a sample of weapons, the average tariff rate for the EEC varied between 5% and 15%; for the UK the range was 0-30%, whilst the USA imposed tariffs of up to 46%. Similarly, in the 1960's, British military aircraft were protected by a tariff rate of between 30% and 50%: the decision to buy TSR-2 rather than F111 was equivalent to imposing a notional tariff of 100% or more on the US aircraft.[2] Nominal tariff rates are a crude indicator of the gains from free trade in weapons.

d) A balance of trade index, of which there are a number of variants. One measure for each commodity group is $\frac{X-M}{X+M}$ *where* X = exports and M = imports. The closer is the ratio to +1, the greater is a country's competitive advantage.[3]

e) Unit labour costs and international differences in productivity, which, taken together, will determine unit costs and competitiveness (see chapter 1, section 1.6 and Figures 1.1 and 1.2). In 1970, US hourly labour costs were some 2.5 times the British level whilst labour productivity was about twice that in the UK.[4]

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1. J. Hughes and A. Thirlwall, Trends and Cycles in Import Penetration in the UK, Oxford Bulletin, Nov. 1977.

2. Cmnd 2853, Report of Committee of Inquiry into the Aircraft Industry, (Plowden), HMSO, London 1975, chp.17.

3. S. Aranovitch and M. Sawyer, Big Business, op. cit., p.249.

4. C. Pratten, Labour Productivity Differentials Within International Companies, Department of Applied Economics, Cambridge, Occasional Paper 50, 1976, p.79.

Of course, aggregate data conceal a nation's competitiveness by product group. Table 2.8 shows an example in one of the few instances where published data are available for both costs and productivity in a given industry. It indicates the type of data which would be required to assess international competitiveness in weapons markets.

Table 2.8 1970 Data

	Total hourly labour costs . UK = 100		Productivity: gross value-added per person . UK = 100
	Engineering	Chemicals	Chemicals
W. Germany	141	151	147
France	105	122	164
EEC	131	138	151[1]
USA	264	263	n.a.

Sources: G. Ray, Labour Costs and International Competitiveness, NIESR Economic Review, Aug. 1972; D. Jones, Output, Employment, and Labour Productivity in Europe, NIESR Economic Review, Jan. 1976.

Note: 1. EEC - Five only.

2.7 (iii) A Survey of Evidence

Evidence from various international studies of comparative advantage, productivity and the EEC provide some insights into the possible effects and benefits of a NATO free trade area in weapons. Some of the evidence can be summarised:-

a) The USA has a strong and increasing comparative advantage in research-intensive products (e.g. aircraft, satellite communications, titanium, office machinery, chemicals, computers). Aircraft continues to occupy first place on the American comparative advantage scale.[1] By contrast, research-intensive industries do not rank among the first ten on the comparative advantage scale of the other major industrial nations. Instead, the 'revealed' comparative advantage of the EEC mirrors the US disadvantage in non-durable consumer goods - e.g. clothing and textiles. Also, the USA is at a relative disadvantage in shipbuilding (which is labour intensive).[2] However, these are no more than broad generalisations and do not imply that Europe has no comparative advantage in any areas of high-technology. A recent US study of relative price advantages within NATO concluded that 'There does not appear to be any distinct pattern with respect to the "high technology-low technology" distinction.[3] - e.g. Europeans are price competitive in some relatively high

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1. B. Balassa, Revealed Comparative Advantage Revisited, 1953-71, Manchester School, Dec. 1977; also, OECD Gaps in Technology: Electronic Computers, Paris, 1969: the large trade surplus of the USA in data processing equipment illustrate the advantages of technological leadership (p.51).

2. B. Balassa, op. cit., The OECD study of Gaps in Technology, General Report, Paris 1968 suggested that US firms have exploited commercially the results of European inventions and fundamental research (p.17).

3. C. Wolf, Trade Liberalization as a Path to Weapons Standardization in NATO, International Security, Winter 1978, p.143.

technology fields (Harrier VTOL aircraft and Roland II missile). Nor should too much emphasis be placed on past performance. The whole point about technical progress is that it does not follow precedents: it creates them!

b) International trade advantage - at least for EEC nations - appears to be positively related to relative plant size (i.e. plant level economies of scale seem more important than firm level economies).[1] However, relative plant size is only a crude indicator of international differences in productivity. For example, in 1968, median plant size in British manufacturing (480 persons) was larger than in the USA (420 persons); but output per head was so much greater in the US, that the median American plant's net output was just over double that of the median British plant.[2] Indeed, the evidence generally shows that US productivity is higher than in the UK, France, Germany and Sweden.[3] In the case of France, it has been estimated that over 19 manufacturing industries, the average US-French labour productivity ratio was 2.06, with the American "advantage" in the capital intensive industries (e.g. cars, chemicals, machinery).[4]

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1. N. Owen, Scale Economies in EEC, European Economic Review, 7, 1976, p.152-153.

2. S. Prais, op. cit., p.144-162. In making the US-UK comparisons, Prais uses a purchasing power parity exchange rate of £1 = \$3.1 in 1968 (official rate was £1 = \$2.4, p.284). With international differences in wages, high labour cost nations, such as the USA, are likely to operate larger plants to be cost competitive (i.e. to reduce man hours). For turbine generators, mes in W. Europe is 8,000 - 10,000 MW, compared with 15,000 MW in the USA, D. Burn and B. Epstein, Realities of Free Trade: Two Industry Studies, op.cit., p.74.

3. F. Scherer, et al, Economics of Multi-Plant Operations, op. cit., p.73. A study of 8 industries gave the following productivity indices (US = 100, output per worker): UK = 47; France = 68; W. Germany = 58; Sweden = 75.

4. K. Chandraseker, US and French Productivity in 19 manufacturing Industries, Journal of Industrial Economics, April 1973.

Differences in rates of output and length of production runs are a major explanation (but not the only one) of the productivity differentials between the USA and Europe, including the UK.[1]

c) Studies suggest that the benefits of West European customs unions are not great - the gains are estimated to be quite small, as little as 1% of Community GNP.[2] The reasons for such small "benefits" are significant for weapons standardization policies. First, only a small part of total output enters international trade. Second, examples of really costly protection are rare. In other words, most of the gains from international trade based on comparative advantage are already being obtained, since no nation can afford NOT to reap them. Applied to weapons standardization policies, such conclusions imply that the likely gains from a free trade area in weapons might be quite small (i.e. most of the gains are already being reaped)! However, the advocates of standardization policies might claim that weapons are one of the few instances of really costly protection, in which case there are likely to be significant benefits. In this context, one study of Britain's entry into the EEC suggested that the gains from free trade might be equal to the additional benefits of increased scale economies - i.e. the total gains could be twice the gains from scale economies only.[3]

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1. C. Pratten, op. cit., 1976, p.28; Haldi and Whitcomb, op. cit.

2. D. Swann, The Economics of the Common Market, Penguin, 1970, p.36.

3. J. Williamson, in J. Pinder (ed.), Economics of Europe, Knight, London, 1971. Williamson assumes that where scale economies apply, they are typically about 20% (p.35). Prior to entry, the U.K. effective tariff was 16%. Williamson concluded that the benefits from entry would be ½% each from scale economies, free trade and investment (=1½% on GNP) - i.e. scale and free trade each contributing ½% on GNP (p.45). Trade creation can be estimated: ½ x tariff cut x increase in imports.

d) Industrial studies of the effects of free trade frequently show a diversity of experience even within one product group. For example, with chemicals, a free trade area between the USA and the UK would result in each nation having a comparative advantage in different sectors of the chemicals industry.[1] Similarly, a study of the EEC concluded that '... the position of Britain's manufacturing industries relative to the EEC's is not a matter of right-across-the-board strength of some sectors accompanied by marked weakness of others, but rather of each sector having its more promising and its relatively vulnerable parts.'[2]

2.7 (iii) Conclusions: The implications of a free trade area in weapons?

A number of pieces of evidence suggest that there are potential and substantial gains from free trade in weapons. First, there are differences in relative prices. For example, some British weapons are not price competitive with US equipment (e.g. fork lift trucks); whilst for turbo-generators in North America, UK prices have been 10%-20% below the prices quoted by US suppliers.[3] Second the evidence on tariffs. Nominal tariffs are misleading indicators of protection. In 1971 effective rates of protection were higher

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1. D. Burn and B. Epstein, *op. cit.* p.252.

2. S. Han and H. Liesner, *Britain and the Common Market*, Department of Applied Economics, Cambridge, Occasional Paper 27, 1971, p.99

3. CPRS, *Future of UK Power Plant Manufacturing Industry*, HMSO, London, 1976, p.56.

than nominal rates by a factor of about 33% for the UK and some 60% for the EEC.[1] For the UK, some of the highest effective rates of protection applied to the engineering sector (e.g. 38.5% for electrical machinery). European countries also seem to protect their R & D intensive industries.[2] Third, defence industries are likely to be heavily protected, especially when it is remembered that domestic governments use preferential purchasing policies (see example of TSR-2 and F111). In the circumstances, we would guess that a free trade area in weapons is likely to produce additional cost savings of some 10% across the board - and this is likely to be a lower bound estimate. The figure is based on the following:

a) A nominal tariff rate of some 10% is taken as typical for NATO nations (full forward shifting is assumed).

b) The gains from free trade might be similar to the savings from scale economies - and a figure of 10% was plausible for scale effects.

c) We can be fairly confident about this estimate. Once effective rates and government preferential purchasing are allowed for, the savings could be as high as 20-30%, at least for some weapons.

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1. NIESR, The Common Market, Economic Review, Aug. 1971, p.41.

2. M. Constantopoulos, Labour Protection in Western Europe, European Economic Review, 5, 1974.

Chapter 3 Industry Case Studies and International Competition

3.1 Introduction

This chapter surveys the evidence on a limited number of industry studies, namely, motor vehicles, steel and aerospace, taking the UK as a starting point. Motor vehicles and steel are presented as "models" for studies which we have argued are required for weapons industries. Both are well-documented, with detailed cost-quantity information and international comparisons. For vehicles, there are data on the minimum efficient scale for engines and final assembly, as well as evidence on the potential gains from freer trade and the associated resource effects. Whilst the studies are based on vehicles industries in aggregate, they can be used to provide some insights into the economics of military vehicle manufacture. The steel industry is included because it is one of the few sectors where there are satisfactory data on both the shape of scale curves and their relative positions between nations. For this industry, we can apply the model developed in chapter 1 and presented in Figures 1.1 and 1.2. As a result, estimates are made of the cost savings of achieving scale economies in each nation as well as any further gains from free trade. Finally, aerospace is included as an example of a defence industry for which cost-quantity data are available.

3.2 (i) The UK Motor Industry: Cars and Commercial Vehicles

For UK car manufacture, minimum efficient plant size (identical units per plant per annum) for various operations is:[1]

i) Casting of engine block - 100,000 units p.a.

ii) Engine and transmission machining and assembly - 500,000 units p.a. Typically, these components represent some 20% of the unit factory cost of a mass-produced car.

iii) Pressing - 1 million units p.a. A car body might represent 40% of the unit factory cost of a volume car.

iv) Final assembly - 250,000 units p.a., with assembly forming 5% of unit factory cost.

The figures suggest that car firms can gain from standardizing on one basic engine and one body, so obtaining economies of machining and pressing. Of course, in private, competitive markets, no firm can afford to use the same engine as its rivals; but such problems are likely to be absent in the military sector with its emphasis on standardization and inter-operability. In addition, weapons standardization in vehicles might reduce duplicate development which could lead to substantial cost savings. For example, a new model of car, including new major components, might cost about £75m (1972 prices), although a more typical figure for initial cost is £12m - 25m (1972 prices).[2]

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1. CPRS, Future of the British Car Industry, HMSO, London 1975; G. Maxcy and A. Silberston, The Motor Industry, Allen & Unwin, London, 1959.

2. D. Rhys, Economies of Scale in the Motor Industry, Bulletin of Economic Research, Nov. 1972; also, C. Pratten, op. cit., 1971.

Recent UK evidence suggests that individual firms with an average annual production below 750,000 vehicles will find it difficult, if not impossible, to compete in volume car markets.[1] On this basis, British Leyland and Ford have sufficient volume to achieve most of the worthwhile scale economies. However, it seems that both plant and firm level economies continue up to at least 1.2 million units p.a., with US evidence suggesting further economies at output levels greater than 2 million units per annum.[2] Table 3.1 summarises the relationship between unit costs and scale for cars.

Table 3.1 Unit Costs for Cars

Change in Output	Proportionate change in unit costs
From 50,000 to 100,000 units, p.a.	Cost savings of 15% - 20%
From 125,000 to 175,000 units, p.a.	Cost savings of 5% - 6%
From 300,000 to 1,200,000 units, p.a.	Cost savings of 17%

Source D. Rhys, op. cit., 1972

With heavy commercial vehicles, annual outputs of 30,000 - 50,000 units reduce unit costs by 25% compared with a production run of 1,000 - 3,000 units per year. However, in the UK heavy commercial vehicles market, small firms survive because they specialise in meeting,

1. CPRS, op. cit., 1975, p.23.

2. D. Rhys, op. cit., 1972. The relationship is $\log Y = \log 2.4 - 0.259 \log X$, where Y = price per lb and X = annual output; $R^2 = 0.9$.

and responding to, specific customer requirements - i.e. the small specialist firms make a distinctive product which is not easily duplicated by the mass production firms.[1]

A study of the UK car industry also indicates the potential gains from free trade in vehicles and the associated implications for the structure of the British industry. Between 1963 and 1975, the UK car industry had declined from being the second largest producer to the fifth largest (outside N. America), having been overtaken by France, Italy and Japan. For example, in the early 1970's, British-Leyland produced under 1 million units per year, compared with 1.26 million for Peugeot-Citroen, 1.5 million for Fiat and over 2 million for Volkswagen. Imports have risen from 5% of the domestic British market in 1965 to some 35% in 1975. Tariff reductions are part of the explanation. Since 1968, UK import duties on cars and commercial vehicles have been reduced from 22% on all cars to 11% on Japanese cars and 4.4% on EEC vehicles. Compared with West European firms, British manufacturers are at a cost disadvantage of about £130 on a typical car priced at £1,150 (1975 prices) - i.e. approximately 10%, which is a crude indicator of the gains from freer trade (cf tariffs on cars).[2] Although British hourly labour costs are lower than on the Continent, UK productivity is also lower - e.g. for the assembly of the same or comparable models, the lower labour costs are not sufficient to offset the lower productivity, the result being that labour costs per unit assembled in Britain are higher.[3] However, as

1. D. Rhys, Heavy Commercial Vehicles, Journal of Industrial Economics, July 1972.

2. CPRS, op. cit., 1975, p.93.

3. Ibid, p.89. For car assembly, labour costs per unit on the Continent are typically some 75% of British labour costs per unit.

a further insight into the implications of free trade, it seems that the UK car components industry is competitive in price and quality with Continental suppliers. In other words, within Europe, the UK might be competitive in certain sectors of the car industry.

An official report on the British car industry suggested rationalization.[1] For example, reducing the number of major models by about 50% was expected to reduce total capital expenditure requirements by some £85 million per year and reduce unit costs by about 3-4% (at current volumes). However, rationalization is expected to lead to the closure of at least 2 British car assembly plants (equal to 400,000 units): evidence of the adjustment effects on capital and labour resources. Similar conclusions about productivity apply when comparisons are made with the US car industry. There is a major difference in scale. In 1968, the American industry's total output was five times that of the UK and the average output of each model made by the 3 leading companies was 400,000 in the USA and 100,000 in Britain.[2] Not surprisingly, the productivity of US car workers is over twice that of his British counterpart and, whilst labour costs tend to be lower in Europe, it seems that US cost levels are still significantly below European levels.[3]

3.2 (ii) Conclusions: The implications for military vehicles

The available evidence is for civil cars and heavy commercial

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1. Ibid, p.123f.
2. C. Pratten, op. cit., (1971), p.327.
3. D. Rhys, Economies of Scale in the Motor Industry, op. cit., 1972, pp.94-95.

vehicles. Nevertheless, the information can be used to hazard some guesses about the scale curves for <u>specialist</u> military vehicles (including tracked vehicles: see data requirements in Chapter 2). It is quite likely that most European nations are producing relatively small quantities of their specialist military vehicles. If so, they might well be operating over a range where the scale curves are steeply sloped, so that there could be <u>major</u> cost savings from larger outputs (via standardization). For example, the data on heavy commercial vehicles suggested a 25% unit cost reduction as annual output rises from 3,000 to some 30,000 units. The scale curves for cars support such figures. For example, as the annual output of cars rises from 1,000 to 50,000 units, average costs fall by 40%, with a further 15% reduction as output is doubled from 50,000 to 100,000 units. In other words, if a nation's specialist military vehicle output (defined widely) is below 30,000 - 50,000 units per year, it could be incurring a substantial cost premium. Of course, such cost disadvantages are much less for military versions of civil vehicles (e.g. cars) where firms can obtain scale economies from supplying private markets. The estimates for specialist military vehicles could also be misleadingly high if such weapons include "standard" components which are manufactured on a much larger scale (e.g. engines).[1] In addition to any cost savings from operating at a larger scale, further gains of at <u>least 10%</u> could be available from free trade.

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1. In the UK, we obtained some interview evidence on tank manufacture. This suggested that:
   a) the R & D cost for a new tank is about $100m.
   b) the scale curve for tanks is typically L-shaped and that <u>mes</u> could be as low as 300-400 tanks per annum - the UK is slightly below this figure. The <u>mes</u> figure seems surprisingly low i was explained that even with tanks, components suppliers ca obtain scale economies through the use of civil components (e.g. engines) and they also benefit from the experience of ci production (e.g. learning, also they might be able to use existing jigs and tools).

3.3 (i) The Steel Industry: Some International Comparisons[1]

The steel industry is included in our survey because it is well-documented and is one of the few industries for which there are satisfactory data on both the shape and relative position of long run average cost curves both within and between nations (see chapter 1, Figures 1.1 and 1.2).

For UK steel-making, minimum efficient scale (mes) is some 2 million tons annually, but for fully-integrated plants, economies continue up to 10 million tons per annum. Firm level economies result in unit costs continuing to fall up to an annual output of 16 million tons, although the rate of decline of unit costs is probably small. Table 3.2 shows the total unit production costs in integrated plants producing hot-rolled strip.[2] Although the data refer to the UK they are consistent with estimates which have been made for steel manufacture in the EEC.[3]

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1. This section is based on A. Cockerill, The Steel Industry, Department of Applied Economics Occasional Paper 42, Cambridge U P., 1974.

2. Some of the estimates of costs below mes are higher than in Table 2.3.

3. Cockerill op. cit., p.88.

Table 3.2

Scale of plant (million tons of crude steel, p.a.)	Total unit costs (Index 10.0 million tons = 100)
0.1	593
0.5	197
1.0	155
2.0	136
4.0	119
8.0	105
9.0	102
10.0	100

Source: A. Cockerill, The Steel Industry, op. cit., 1974, p.84.

The table indicates an mes for hot-rolled strip of 8 million tons annually (i.e. where a further doubling of output will reduce unit costs by 5%). Costs rise sharply at relatively low output levels, and at one-quarter of mes, unit costs increase by 30%. Interestingly, a doubling in output, from 0.5 to 1 million tons reduces unit production costs by about 20% and further doublings reduce average costs by about 12% - i.e. equivalent to an 87-88% unit production cost curve for every doubling in output (c.f. learning curves).

Are there international variations in the slope and position of the scale curve? The above estimates are based on UK cost structures

and factor prices. Once allowances are made for international cost variations it seems that the greatest difference in the SLOPE of the scale curve arises for Italy (i.e. from a sample consisting of the UK, USA, Canada, Benelux, W. Germany, France and Japan). Even so, at scales greater than 5 million tons annually, "the difference in the slopes of the scale curves for each country caused by factor price variations is not significant ... "[1] Table 3.3 shows differences between countries in the POSITION of the scale curve. Italy is the lowest cost nation. Assuming that all capacity is in plants of mes (8 million tons), differences in factor prices do not affect substantially (i.e. within 5%) the relative competitiveness of most major nations. Britain and America (and Canada) are the exceptions: for these nations, even at outputs greater than 10 million tons, unit costs are always substantially more than 5% above those at mes in Italy.[2] Differences in capital costs might affect these generalisations, but even so, it has been concluded that "... in general, factor cost variations do not influence the minimum efficient scale of output."

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1. Cockerill, op. cit., p.90.

2. Ibid p.92.

Table 3.3 Position of Scale Curves

Nation	Annual Capacity of 8 million tons (= mes) Unit Cost ($)	Index (Italy = 100)
France	66.2	103
W. Germany	67.0	105
Italy	64.1	100
UK	80.5	126
USA	80.5	126

Source: Cockerill, *op. cit.*, p.91.

The above analysis *assumed* plants of mes. To what extent do such plants actually exist in each country? An international efficiency ratio can be constructed based on the proportion of total capacity in large scale plants. On this basis, the USA, Canada, Netherlands and Japan were highly efficient in the late 1960's; Italy and W. Germany were moderately efficient and the UK, France and Belgium-Luxembourg were inefficient. These rating provide a crude indicator of comparative advantage in the world steel market. Indeed, a nation's share of world steel exports can be "explained" by its proportion of capacity in efficient plants.[1] However, for each nation to reach the *mes* for steel making would require considerable rationalization. Table 3.4 shows the actual number of plants and firms in existence in 1968 in relation to the number which could be

1. The proportion of efficient plants "explains" some 80% of the variations in export share. Cockerill, p.106.

supported if each were of <u>mes</u> - e.g. W. Germany could only support some 4 plants and 3 firms, requiring the closure of 32 plants and 22 firms!

<u>Table 3.4 Steel-making, 1968</u>

Nation	Plants		Firms	
	Actual	Theoretical	Actual	Theoretical
France	48	2.3	26	1.5
W. Germany	36	4.4	25	2.9
Italy	32	2.2	26	1.4
UK	70	2.9	27	1.9
USA	142	17.2	91	11.5

<u>Source</u>: Cockerill, <u>op. cit.</u>, p.110.

3.3 (ii) <u>Conclusions. Steel and the implications for weapons standardization</u>

The cost data on steel can be used to provide some intelligent guesses about the likely cost savings of any policy which allowed all major nations to operate at <u>mes</u>. Table 3.5 shows the range of savings available to each country, with a typical figure of almost 50%.

Table 3.5 Estimates of Cost Savings for Steel-making

Nation	Average output per plant, 1968 (000 tons)	Percentage of mes (%)	Unit cost savings from operating at mes (%)
France	376	5	61
W. Germany	971	12	32
Italy	541	7	47
UK	330	4	65
USA	968	12	32

Notes: 1. mes is assumed to be 8 million tons, p.a.

2. Unit cost savings estimated from Table 3.2 - the savings are in relation to current cost figures for each country.

Additional to the savings estimated in Table 3.5, with all firms at mes, there might be further gains from free trade in steel. Table 3.3 showed that the UK and the USA might obtain further cost savings approaching 20%, although this is likely to be an upper bound estimate, since there are offsetting transport costs for a bulky product like steel.[1] As Table 3.3 shows, the remaining nations are unlikely to obtain substantial gains from free trade in steel. Thus, for defence industries which are similar to steel, the evidence suggests that weapons standardization policies which lead to operation at mes will result in unit cost savings of some 50%.

1. At an output of 10 million tons, both UK and USA have a cost index of 120 compared with Italy = 100.

If, in addition, standardization leads to a free trade solution, there might be further gains of under 20% available to some nations, such as the UK and USA. These estimates are amongst the highest in our study. Admittedly, they are based on the steel industry but, if weapons standardization policies were to achieve similar savings, they would be truly "beneficial"!

3.4 Aerospace: Cost Quantity Relationships and International Comparisons

3.4(i) Introduction

Aerospace is one of the few defence sectors where there are adequate cost-quantity data. This section will review some of the cost evidence, especially for the UK and Western Europe; undertake some international comparisons, particularly with the USA; and consider the cost implications of alternative standardization policies, including joint projects and co-production.

3.4(ii) The evidence on cost-quantity relations

Aircraft are "classic" candidates for standardization policies: high unit values and relatively short production runs, particularly in Europe. As a result, high R & D costs have to be spread over small outputs and there are fewer opportunities for production learning economies (see chapter 1, section 1.4). Some examples of UK and European R & D costs are:

a) Tornado £845m (1976 prices)

b) RB 211 £200+m (original estimate, 1970 prices)[1]

c) Complex Avionics £30m-£100m.

Note: the US "equivalents" have to be costed using an R & D exchange rate - e.g. £1 = $5.5.

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1. Department of Trade and Industry, Rolls Royce Ltd., HMSO, London, 1973.

In production work, labour learning curves of 80% are
in the UK aircraft industry, at least up to some 100 units. Th
be converted into unit production cost curves with a simple form
the reduction in unit production costs is likely to be about one-
the reduction in direct labour costs alone.[1] Thus, an 80% labou
learning curve results in a 90% unit production cost curve - i.e.
production costs decline by about 10% for each doubling in cumula
output. Typically, US labour learning curves have steeper slope
implying slightly greater savings on average costs, as shown in T
3.6.

Table 3.6 US Cost Curves

Product	Labour Learning Curves(%)	Unit Producti
Aircraft	75	87.5
Missiles	87	93.5
Jet Engines	90	95.0

Source: J. Large, et al, Production Rate and Productio
Rand, R1609, 1974.

Advocates of standardization policies require a general
matrix enabling them to assess some of the cost implications of al
policies. Table 3.7 is an example of a basic framework (illustra

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1. Assume that wages represent about 50% of total factor payment
formula for the unit production cost curve (UPC) is: UPC =
$[1 - \frac{1}{2}(1-S)]$ where S = 80% for aircraft (slope of learning

showing the relative importance of R & D, labour and production costs at various outputs for a "typical" aircraft (civil): note the decline in average R & D costs and in their relative importance in total unit costs as output rises.

Table 3.7 Costs and Output

Output	Average Labour Cost	Average Production Cost	Average R & D Cost	Average Total Cost
1	2.43	9.6	200.0	209.6
50	0.98	5.7	4.0	9.7
100	0.8	5.2	2.0	7.2
200	0.65	4.7	1.0	5.7
400	0.52	4.23	0.5	4.73
800	0.42	3.81	0.25	4.06
1600	0.34	3.43	0.125	3.56

Source: Adapted from S. Sturmey, Cost Curves and Pricing in Aircraft Production, Economic Journal, Dec 1964.

Notes: i) The costs are in "units" for airliners - e.g. for a large jet transport each unit would represent £200,000 at 1963 prices: giving a total launching cost of £40m, or £80m-£130m in 1974 prices.

ii) Labour costs based on 80% learning curve. Production costs based on a 90% curve.

iii) Production costs include bought-out parts and components - e.g. engines, electronics. The figures for a military aircraft will differ.

Table 3.7 can be used to show the savings from standardization. The "ideal" case for standardization would be, say, 4 nations each producing an aircraft costing 200 "units" for R & D ("duplication"), with an average output of 200 planes each (short runs). What would be the savings if all nations agreed to buy from one supplier? CETERIS PARIBUS, 3 R & D bills would be saved and production (learning) economies would be gained through increasing output from 200 to 800 units in one firm. Table 3.7 shows that, as a result, unit costs would fall by almost 30% - and this is obviously an upper bound estimate of the savings from scale effects as output increases four-fold (moving along a scale curve: see Figure 1.1(a)). Such an estimate is subject to qualification:

a) The ceteris paribus clause must be stressed. In fact, evidence suggests that each nation will demand modifications, which will tend to raise R & D budgets and reduce some of the economies from a long run.

b) R & D costs tend to escalate. In the mid-1960's, typical cost escalation factors for military aircraft and missiles were 2.7 for the UK and 2.9 in the USA.[1] If standardization eliminates competition, will cost escalation factors be higher?

3.4 (iii) International comparisons: the UK, Europe and the USA

In addition to scale effects, standardization might result in further savings if aircraft production is based on comparative advantage

1. Cost escalation is the relationship between original development cost estimates and actual outlays, expressed in constant prices. K. Hartley and J. Cubitt, Cost Escalation in the UK; Civil Service, Expenditure Committee, Appendix 44, HCP 535, HMSO, London 1976-77.

are typically some 75% of British labour costs per unit.

(free trade: see Figure 1.2). At best, we suggested that the extra gains from free trade might equal the savings from scale effects - i.e. an extra 30%, which might not be unrealistic, since it has been claimed that the USA is the lowest cost source of supply and is probably 20%-30% more efficient than Europe. Table 3.8 shows the difference in size and scale between the leading American and European aircraft firms. US output levels, either by top company or groups, is some 2-3 greater, and productivity 1.5 times higher, than in Europe. In fact, the productivity figures in Table 3.8 under-estimate the US advantage. Once consideration is given to the whole industry and to net output, U.S. labour productivity is about 3 times that in the UK and 1.5 times that in France.[1]

Table 3.8 Size of Firms, 1975

	Sales (S) (European units of account, m)	Employment (N)	Productivity ($\frac{S}{N}$)
Largest Firm:			
USA	2817	72,600	38.8
UK	1008	60,941	16.5
France	1271	36,000	35.3
W. Germany	496	18,565	26.7
Top Group:			
USA	12,170	327,797	37.1
Europe	4,512	185,536	24.3

1. R. Harvey, Diagnostic Charts for Aerospace Productivity Improvement, Aircraft Engineering, March 1978.

Table 3.8 cont.

Source: EEC, European Aerospace Industry: Trading Position and Figures, Brussels, 1977.

Notes: i) Sales figures are turnover - ideally value-added data are required, especially for productivity estimates.

ii) The leading firms (sales) are Boeing, Aerospatiale, Rolls Royce, VFW. The top group is Boeing, Lockheed, McDonnell, P & W, GD and Grumman in USA and Aerospatiale, RR, Dassault-Brequet, BAC, VFW and MBB in Europe.

The major explanation of the "productivity gap" is the small scale of airframe production in Europe.[1] For combat aircraft, US production runs of 1000 of a type are typical, sometimes extending to 3-5,000 (F4, F5), at rates of 12-14 aircraft per month, with up to 30-45 aircraft per month not unknown. In the UK, a typical production run is 200-300 aircraft (Harrier, Hawk, Lightning) at the rate of 2-4 per month. Production runs for joint projects are longer, with over 400 for the Anglo-French Jaguar and 805 for the 3-nation Tornado (at 7 per month).[2] Production rate has a major impact on cost. An increase in the rate from 1 to 12 aircraft per month, might reduce unit production costs by over 15%.[3] Nevertheless, the Europeans have a comparative advantage in certain areas of aerospace.

Interviews with US aircraft firms indicated that the UK has a relative advantage in sub-systems, such as ejector seats and avionics (e.g. head-up displays and simulators), together with engines, VTOL aircraft and small missiles. Evidence also suggests that for a given design-

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1. Ministry of Technology (Elstub), Productivity of the National Aircraft Effort, HMSO, London, 1969. Once allowance is made for output differences, the ratio of productivity in the USA and Britain in the late 1960's was between 1.2-1.5:1.

2. Parts of this section are based on the author's NATO Research Fellowship study tour of the USA and UK: they will be reported to NATO in 1979 and are not to be quoted without the author's permission. See also, R. Facer, Weapons Procurement in Europe: Capabilities and Choices, IISS , Adelphi Paper 108, London, 1975.

3. J. Large, et al, op. cit., 1974.

development task, the UK has lower costs than the USA. For example, a comparison of the VC-10 and 707 airliners estimated that design man hours were 9% lower on the UK aircraft - and our wages are lower. Similarly, Rolls Royce estimated that in 1968, a given project team cost £80,000 in the UK and $478,000 in the USA, so that British development costs were half the American level (official exchange rate £1 = $2.8, although the results give an R & D exchange rate of £1 = $5.98).[1] On this basis, the UK might have a comparative advantage in aerospace design and development - suggesting that the UK should specialise in development when collaborating with the USA! On manufacturing, the position is different.

Interviews with the UK aircraft industry suggest that Britain is possibly a lower cost supplier on small production runs.[2] Up to some 150-200 units, Britain is likely to be cheaper on average production costs. On man hours, the UK learning curves are below US curves up to about 100 units. But British learning curves "flatten out" after 100 units, whilst learning continues in the USA (the French also claim that their learning continues indefinitely). As a result, when output exceeds 200 units, the USA is superior on both man hours and unit production costs; and hence has an advantage on long runs. The outcome is presented in Figure 3.1, which should be compared with Figures 1.1 and 1.2. This has implications for weapons standardization policies. It might be misleading to project cost curves beyond a firm's output experience - e.g. the UK has no experience of operating at US scales

1. Ministry of Technology (Elstub), op. cit., chps. 6 and 8.

2. Based on author's NATO Research Fellowship: confidential and not to be quoted without permission.

of output of rates of production.

Figure 3.1

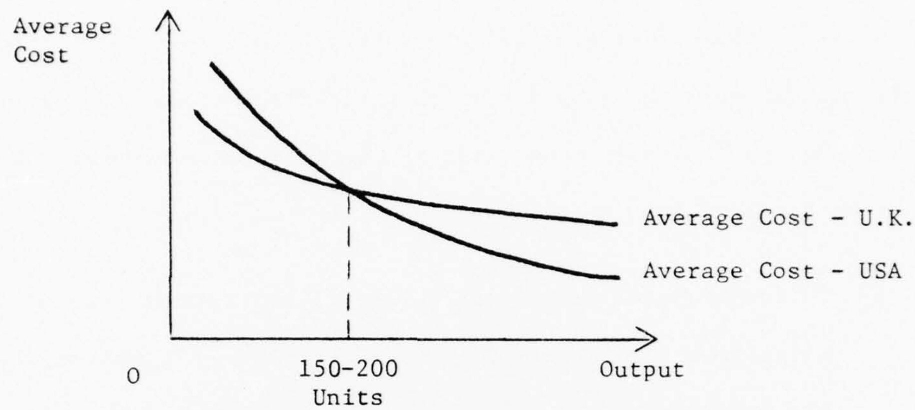

Table 3.9 gives examples of continental European and US learning curves for a given and identical aircraft.[1] In general, US learning curves have higher man hours for the first unit but a steeper slope than in continental Europe - i.e. the relationship is similar to that between the UK and USA (Figure 3.1-see firm B in Table 3.9).

Table 3.9 US and European Learning Curves

European Company A		US Firm		European Company B	
Wings only:				Fuselage only:	
assembly	80%	Wings - assembly	70%	Output 1-100	75%
wing box installation	85%	Major assembly	71%	Output 100-300	80%
		Sub-assembly	72%	Output 300-500	85%
mechanical manufacturing	90%	Fabrication	77%	Output 500+	100%

1. Ibid.

3.4 (iv) The costs of alternative standardization policies

Compared with nationalism, there are 3 broad options for aerospace standardization policies, namely "off-the-shelf" purchases from an established supplier, joint projects (European style - e.g. Tornado) and licensed production or co-operation. Evidence on the costs of each policy is:

a) "Off-the-shelf" purchases. This is the classic case of the gains from standardization (see Table 3.7). Consider the UK Phantom "buy". If the UK had bought Phantoms "off-the-shelf" from McAir, their unit prices would have been some 23-43% lower.

b) Joint projects where two-three nations share both the development and production work (e.g. Jaguar, Tornado). Evidence suggests that the total R & D bill for joint projects is greater than would have been incurred if only one nation had undertaken the work. Typically, the total R & D costs on a joint venture might be 20-70% higher, depending on the number of partners.[1] Even so, with two partners and equal sharing, each nation will "save" on its R & D bill so long as a joint project costs under twice a one-nation only venture. Similarly, unit production costs are claimed to be lower, simply because a joint venture with a larger output, allows greater opportunities for scale and learning economies than would be available on a national programme. For

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1. R. Facer, Weapons Procurement in Europe, op. cit., p.37. On Tornado, a collaboration premium of 50% for R & D has been estimated and 15% for production: W. Walker, MRCA: a case study, Research Policy, Jan. 1974.

example, the UK requires 385 MRCA's but "benefits" from a total output of 805 aircraft. Admittedly, there are some extra production costs involved in a joint venture, namely, the costs of co-ordination and duplicate final assembly lines. However, these can be exaggerated. For example, final assembly accounts for some 20% of production costs, and duplicate assembly lines might raise unit production costs by as little as 1-2%. In total, joint ventures might incur a 5% premium on unit production costs, compared with a single source alternative for the same output. Much depends on the standard for comparison. For a given output, joint ventures involve extra costs compared with least-cost single suppliers. But compared with, say, a UK national output, joint ventures give "savings" to Britain: these might be between 10% and 18% on total unit costs (R & D and production and a doubling of output) At the same time, it is recognised that costs might be even lower if the same aircraft and numbers were purchased under "ideal" conditions from a single supplier.[1]

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1. The author has estimated that MRCA might result in cost "savings" to the UK ranging from £640m to £1900m, with an average of £1,200m - depending on the assumptions about R & D and production costs for IDS and ADV types. The reader can experiment with various assumptions using Table 3.7 - e.g. compare a national program of 200 aircraft with an identical 2 nation venture of 400 aircraft, assuming a 50% premium on R & D and a 5% premium on production costs at 400 units: the unit costs of the joint venture will be 5.19 compared with 5.7 for a national venture and 4.73 for a single supplier of 400 units. We might guess that joint projects achieve about half the savings which could be obtained in the "best" case.

c) Co-production and licensed production. Most firms believe that this option results in higher unit costs than if the output had been obtained from the main manufacturer. These higher costs for the licensed producer or co-producer result from the loss of learning, shorter production runs, duplicate tooling and the costs of transferring technology. Typically, the unit costs of licensed and co-produced aircraft are 10%-20% higher, although there are reputed to be examples where the figure has approached 100%. On one major US program, some 25% European co-production was expected to raise costs by 10%. On the work-sharing arrangement for the UK Phantoms, Britain was willing to pay a 20% premium for UK inputs. Japanese experience with the manufacture of F104's is more surprising. The Japanese obtained the planes at a lower cost than they would have paid in the USA. Mainly because of lower labour rates and some transfer of knowledge (learning) from Lockheed, Japanese unit costs were 88%-90% of US unit costs for a comparable aircraft.[1] Once again, conclusions on licensed and co-production depend on the standard of comparison and the counter-factual (i.e. what would have happened if there hadn't been co-production?). Compared with the "best" case alternative, licensed and co-production might reduce substantially the gains from standardization in weapons acquisition (there

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1. G. Hall and R. Johnson, Aircraft Co-Production and Procurement Strategy, Rand, R450, May 1967.

remain the military "benefits" of standardization). However, compared with separate, independent national programs, co-production should result in some sharing of R & D and possibly some savings in production.[1]

1. Table 3.7 illustrates the possible cost effects. Consider a firm producing 400 aircraft, at an average cost of 4.73. If another nation wishes to licence produce 100 units, it might be expected to operate along the row corresponding to 100 aircraft - i.e. unit production costs of 5.2 with R & D costs now spread over 500 units, giving an average R & D cost of 0.4: hence the main firms' unit costs will fall to 4.63 (saving) and the licensee will obtain 100 units at a unit cost of 5.6 - compared with 7.2 if it had been an independent developer and a unit cost of under 4.63 if it had bought off-the-shelf from the main manufacturer (ceteris paribus). Of course, some of the simplifying assumptions could be relaxed - e.g. if the main manufacturer transfers learning experience, the unit production cost at 100 will be lower than 5.2 for the licensee; or co-production might exploit the benefits of international differences in wages and comparative advantage; or R & D costs might not be shared amongst the total order.

Chapter 4 Conclusions

1. Our survey of the literature suggests that standardization in acquisition could result in savings of the following magnitude:

   a) Scale effects, via a doubling of output, might reduce unit costs by 10%: this is consistent with evidence from both scale and learning curves.

   b) Free trade effects, via competitive markets and comparative advantage could result in further savings of 10%. Not only is this figure derived from international trade studies (e.g. on tariffs and effects of EEC) but it is further supported by evidence on the effects of introducing competition into defence markets. Increased competition in the US defence market reduced production costs by 8%-9%: the figure is likely to be higher in the non-competitive European markets where some major weapons firms are state-owned (e.g. British Aerospace; Royal Ordnance Factories).[1]

2. Our estimates could well be lower-bound figures - there are dangers of double counting and the savings on R & D are not always included in production cost data: hence our caution.

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1. G. Ashcroft, Military Logistic Systems in NATO: The Goal of Integration, Part I, Economic Aspects, IISS, Adelphi Paper 62, November 1969, p.7. Ashcroft reports that competition supposedly reduced US unit prices by some 24%-72% for a sample of weapons components.

3. Where data are unavailable, we would suggest that the <u>10% rule</u> be used as a crude estimate of the savings from a doubling of output.

4. The target sectors and weapons for standardization policies. We suggest a policy emphasis on the industries with the <u>greatest scale factors</u>: see Tables 2.2 and 2.3 - e.g. those industries where, operating at half of <u>mes</u> raises unit costs by 20% or more. Scale and learning factors appear to be inversely related, which suggests the following tentative hypothesis

$$b = 1 - S$$

where b = scale factor - i.e. the increase in unit costs at half mes, compared with costs at mes.

S = percentage slope of the learning curve.

Thus, an 80% learning curve suggests a 20% scale factor - i.e. a 20% increase in costs at half mes; a 90% learning curve gives a 10% scale factor.

5. Our estimates of up to 20% savings from standardization (1 above) are based on the "best case" situation: they will be reduced through adopting higher cost options (e.g. joint projects; co-production; constraints on both competition and free trade).

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